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# COMPTES RENDUS

## (DOKLADY)

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*MATHÉMATIQUES*

# SUR LES DIVISEURS NORMAUX DANS LES GROUPES D'ORDRE IMPAIR

Par W. K. TURKIN

*(Présenté par O. J. Schmidt, de l'Académie, le 21. IX. 1938)*

Dans son article «Quasinormalisateurs et représentations monomiales» (1) l'auteur de la présente Note a montré comment on peut utiliser les méthodes de la théorie des quasinormalisateurs pour obtenir des critères de la simplicité d'un groupe fini. Dans cet article l'auteur a démontré le théorème suivant:

Soit $\mathfrak{G}$ un groupe d'ordre $p^{\alpha}n$ [$p$ est un nombre premier impair; $p(p^{-1})$ est premier avec $n$]. Soit $A$ un élément d'ordre $p^k$ du groupe $\mathfrak{G}$. Si l'ordre du normalisateur de l'élément $A^{p^{k-1}}$ par rapport au groupe $\mathfrak{G}$ n'est pas divisible par $p^{2k}$, le groupe $\mathfrak{G}$ possède un diviseur normal dont l'ordre est divisible par $n$.

Dans l'article de W. Turkin et P. Dubuque «Sur la structure des groupes simples» (2) on trouve la généralisation suivante de ce théorème:

Soit $\mathfrak{P}$ un sous-groupe abélien d'ordre $p^{\alpha}$ d'un certain groupe $\mathfrak{G}$ d'ordre $p^{\beta}n$ ($p$ est un nombre premier impair, $n$ n'est pas divisible par $p$). Soit $A$ un élément d'ordre $p^k$ du sous-groupe $\mathfrak{P}$ et tel que chaque élément de $\mathfrak{P}$ conjugué à $A^z$ est égal à $A^{mz}$, où $m \equiv 1 \pmod{p}$. Si l'ordre du normalisateur de $A^{p^{k-1}}$ n'est pas divisible par $p^{\alpha+k}$, le groupe $\mathfrak{G}$ possède un diviseur normal d'ordre divisible par $n$.

Il est évident que le théorème démontré dans l'article (1) est un cas particulier du théorème démontré dans l'article (2) (cas où $\mathfrak{P} = \{A\}$).

Énonçons un théorème encore plus général:

*Soit $\mathfrak{G}$ un groupe d'ordre $p^{\alpha}n$ ($p$ est un nombre premier impair, $n$ n'est pas divisible par $p$). Soit $\mathfrak{H}$ un sous-groupe d'ordre $p^{\beta}$ du groupe $\mathfrak{G}$ et soit $\mathfrak{K}$ une commutante du sous-groupe $\mathfrak{H}$.*

*Soit $A$ un élément d'ordre $p^k$ du sous-groupe $\mathfrak{H}$ jouissant de cette propriété que chaque élément du sous-groupe $\mathfrak{H}$ conjugué à $A^z$ est contenu dans l'un des systèmes $\mathfrak{K}A^{mz}$, où $m \equiv 1 \pmod{p}$. Soit $A_{pz}$ la plus petite puissance de l'élément $A$ contenu dans $\mathfrak{K}$.*

*Si le produit de l'ordre du normalisateur de l'élément $A^{p^{k-1}}$ et du nombre d'éléments du sous-groupe $\mathfrak{H}$ conjugués à $A^{p^{k-1}}$ n'est pas divisible par $p^{\beta+r}$, le groupe $\mathfrak{G}$ possède un diviseur normal dont l'ordre est divisible par $n$.*

Le théorème, démontré dans l'article (1), est évidemment un cas particulier de ce dernier théorème (cas, où le sous-groupe $\mathfrak{H}$ est abélien).

La démonstration du théorème que nous considérons peut être effectuée par la même méthode que celle des théorèmes précédemment cités, mais avec une certaine complication.

Soit $\mathfrak{A}$ un certain sous-groupe du groupe $\mathfrak{G}$ et soit $\mathfrak{B}$ l'intersection de ce sous-groupe et du sous-groupe $\mathfrak{H}$. Soit

$$\mathfrak{A} = \mathfrak{B} + \mathfrak{B}Z_2 + \mathfrak{B}Z_3 + \ldots + \mathfrak{B}Z_a.$$

Soit ensuite

$$\mathfrak{G} = \mathfrak{H} + \mathfrak{H}G_2 + \mathfrak{H}G_3 + \ldots + \mathfrak{H}G_t.$$

Nous pouvons évidemment supposer que chacun des éléments de $Z_i$ est égal à l'un des éléments de $G_i$.

Soit

$$Z_i A = H_i G_{\lambda_i},$$

où $H_i$ est un élément du sous-groupe $\mathfrak{H}$. Introduisons la notation

$$H_1 H_2 H_3 \ldots H_a = \Pi(\mathfrak{A}, A).$$

Le symbole $\Pi(\mathfrak{A}, A)$ introduit dans le présent article est évidemment une généralisation du symbole $\Pi(\mathfrak{A}, A)$ introduit dans l'article (1).

Nous désignerons par $\nu(\mathfrak{A})$ l'indice du sous-groupe $\mathfrak{B}$ (intersection de $\mathfrak{A}$ et $\mathfrak{H}$) par rapport à $\mathfrak{A}$.

Si l'on prend pour $\mathfrak{A}$ un quasinormalisateur quelconque de $\mathfrak{N}^{(\lambda)}_{A^{p^i}}$, on a $\Pi(\mathfrak{N}^{(\lambda)}_{A^{p^i}}, A) = KA^s$, où $K$ est un élément de la commutante $\mathfrak{K}$ (dans cette formule l'exposant $s$ est évidemment défini à une constante additive près divisible par $r$). Le nombre $s$ sera désigné par $\omega(\mathfrak{N}^{(\lambda)}_{A^{p^i}})$.

On peut démontrer les lemmes suivants concernant les symboles introduits:

I. $\nu(\mathfrak{N}^{(\lambda_i)}_{A^{p^i}})\,\omega(\mathfrak{N}^{(\lambda_i)}_{A^{p^{i+1}}}) = \nu(\mathfrak{N}^{(\lambda_i)}_{A^{p^{i+1}}})\,\omega(\mathfrak{N}^{(\lambda_i)}_{A^{p^i}})$.

II. Si $\mathfrak{N}^{(\lambda)}_{A^{p^i}} \neq \mathfrak{N}^{(\lambda-1)}_{A^{p^i}}$ et $\lambda \leqslant \lambda_{i-1}$, on a $\omega(\mathfrak{N}^{(\lambda-1)}_{A^{p^i}}) = \sigma\omega(\mathfrak{N}^{(\lambda)}_{A^{p^i}})$, où $\sigma \equiv p \pmod{p^2}$.

La valeur de $\lambda_i$ est la même que dans l'article (1): c'est la plus grande valeur de $\lambda$ pour laquelle

$$\mathfrak{N}^{(\lambda)}_{A^{p^i}} = \mathfrak{N}^{(1)}_{A^{p^i}}.$$

Si $\lambda_i = k - i$, on pose dans l'énoncé du lemme I $\mathfrak{N}^{(\lambda_i)}_{A^{p^{i+1}}} = \mathfrak{N}^{(k-i-s)}_{A^{p^{i+1}}}$. Le lemme II reste vrai pour $i = 0$; la condition $\lambda \leqslant \lambda_{i-1}$ n'a plus de sens dans ce cas et il faut la rejeter.

Considérons comme dans l'article (1) la suite des quasinormalisateurs

$$\mathfrak{N}^{(k)}_A, \mathfrak{N}^{(k-1)}_A, \ldots, \mathfrak{N}^{(\lambda_0)}_A$$
$$\mathfrak{N}^{(\lambda_0)}_{A^p}, \mathfrak{N}^{(\lambda_0-1)}_{A^p}, \ldots, \mathfrak{N}^{(\lambda_1)}_{A^p}$$
$$\mathfrak{N}^{(\lambda_1)}_{A^{p^2}}, \mathfrak{N}^{(\lambda_1-1)}_{A^{p^2}}, \ldots, \mathfrak{N}^{(\lambda_1)}_{A^{p^2}}$$
$$\ldots\ldots\ldots$$
$$\ldots\ldots\ldots$$
$$\mathfrak{N}^{(1)}_{A^{p^{k-1}}}.$$

Nous voyons que si $\nu(\mathfrak{N}^{(1)}_{A^{p^{k-1}}}) = p^\delta t$ où $t$ n'est pas divisible par $p$, on a $\omega(\mathfrak{N}^{(1)}_{A^{p^{k-1}}}) = s$, où $s \equiv 0 \pmod{p^\delta} \neq 0 \pmod{p^{\delta+1}}$.

Construisons une représentation monomiale du groupe $\mathfrak{G}$ au moyen du sous-groupe $\mathfrak{H}$ et de sa commutante $\mathfrak{K}$. Le déterminant de la matrice correspondant à l'élément $A$ dans cette représentation est un élément du groupe complémentaire $\frac{\mathfrak{H}}{\mathfrak{K}}$ correspondant au système

$$\mathfrak{K}A^{c\omega\left(\mathfrak{N}^{(1)}_{A^{p^{k-1}}}\right)},$$

où $c$ est le nombre des éléments du sous-groupe $\mathfrak{H}$, conjugués à l'élément $A^{p^{k-1}}$. Ce déterminant ne peut être égal à l'unité que dans le cas où le nombre $c\omega\,(\mathfrak{N}^{(1)}_{A^{p^{k-1}}})$ est divisible par $p^r$. Mais dans ce dernier cas le produit de l'ordre du normalisateur de l'élément $A^{p^{k-1}}$ par le nombre des éléments du sous-groupe $\mathfrak{H}$ conjugués à $A^{p^{k-1}}$ est divisible par $p^{\beta+r}$. Dans le cas contraire le groupe $\mathfrak{G}$ possède un diviseur normal dont l'ordre est divisible par $n$. Ainsi le théorème est démontré.

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*MATHÉMATIQUES*

# SUR LE THÉORÈME FONDAMENTAL DE FROBENIUS

Par P. E. DUBUQUE

*(Présenté par O. J. Schmidt, de l'Académie, le 22.IX.1938)*

Dans son article «Un théorème contenant les théorèmes de Frobenius, de Weisner et de Turkin sur le nombre des éléments d'un ordre donné dans un groupe» dont les résultats essentiels ont été récemment publiés (1) l'auteur démontre la proposition suivante:

«Soit $m$ l'ordre d'un élément dans une classe $\mathfrak{M}$ d'éléments conjugués d'un groupe $\mathfrak{G}$. Soit ensuit $n$ un diviseur de l'ordre du groupe et qui est un multiple de $m$. Le nombre des éléments du groupe $\mathfrak{G}$ dont la $n$-ième puissance appartient à une classe $\mathfrak{A}$ arbitraire d'éléments conjugués et dont une certaine puissance appartient à $\mathfrak{M}$ est un multiple du plus grand diviseur de $n$ premier avec $m$».

Le but de la présente Note est de démontrer le théorème suivant plus général:

*Soit $m$ le plus petit nombre qui est un multiple de tous les ordres des éléments appartenant à un certain complexe invariant $\mathfrak{M}$ d'un groupe $\mathfrak{G}$. Soit $n$ un diviseur de l'ordre du groupe $\mathfrak{G}$ et un multiple de $m$. Le nombre des éléments du groupe dont la $n$-ième puissance appartient à un complexe invariant $\mathfrak{A}$ arbitraire et dont une certaine puissance appartient au complexe invariant $\mathfrak{M}$ est un multiple du plus grand diviseur de $n$ premier avec $m$.*

En particulier, si dans les conditions du théorème on prend pour complexes invariants $\mathfrak{A}$ et $\mathfrak{M}$ des classes d'éléments conjugués, on obtient la proposition citée. Donc, le théorème précédent contient comme cas particuliers les théorèmes de Frobenius (2) et de Weisner (3).

Ensuite, le théorème à démontrer contient comme cas particulier un théorème de W. Turkin (4). Pour obtenir ce dernier il suffit de supposer que dans les conditions de notre théorème le complexe invariant $\mathfrak{M}$ contient tous les éléments du groupe $\mathfrak{G}$ dont l'ordre est égal à $m$ et que le complexe invariant $\mathfrak{A}$ est égal à l'unité.

Dans la démonstration du présent théorème nous ne nous appuyons que sur le théorème fondamental de Frobenius et nous n'utilisons pas le théorème de L. Weisner. Donc, la démonstration que nous donnons ici permet d'obtenir d'une nouvelle manière le théorème de Weisner.

Démonstration. Dans la démonstration du théorème il suffit évidemment de considérer le cas où le complexe invariant $\mathfrak{A}$ est une classe d'éléments conjugués du groupe $\mathfrak{G}$. Établissons d'abord la proposition auxiliaire suivante:

Lemme. *Soient $m_1, m_2, \ldots, m_k$ les ordres des éléments dans les classes $\mathfrak{M}_1, \mathfrak{M}_2, \ldots, \mathfrak{M}_k$ (respectivement) d'éléments conjugués du groupe $\mathfrak{G}$. Soit $m$ le plus petit multiple commun des nombres $m_1, m_2, \ldots m_k$ et $n$—un diviseur de l'ordre du groupe qui est un multiple de $m$. Le nombre des éléments du groupe dont la n-ième puissance appartient à une classe arbitraire d'éléments conjugués $\mathfrak{A}$, dont une certaine puissance appartient à la classe $\mathfrak{M}_1$, une autre puissance appartient à $\mathfrak{M}_2$, etc., enfin une certaine puissance appartient à $\mathfrak{M}_k$, est le plus grand diviseur de $n$ premier avec $m$.*

Nous devons déterminer le nombre des éléments du groupe qui vérifient les conditions simultanées

$$X^n \subseteq \mathfrak{A}, \tag{1}$$

$$X^{\alpha_i} \subseteq \mathfrak{M}_i \quad (i = 1, 2, \ldots, k), \tag{2}$$

où les nombres $\alpha_i$ peuvent être choisis arbitrairement.

Désignons par $bm'$ l'ordre d'un élément $X$ vérifiant les conditions (1) et (2), $b$ étant le plus grand diviseur de $bm'$ premier avec $m$. En appliquant un théorème connu on peut poser maintenant $X = X_1 X'$, les éléments $X_1$ et $X'$ étant permutables et leurs ordres respectivement égaux à $m'$ et $b$. Remarquons pour la suite que

$$X'^{\alpha_i} = 1 \quad (\alpha_i = 1, 2, \ldots, k);$$

donc

$$X_1^{\alpha_i} \subseteq \mathfrak{M}_i \quad (\alpha_i = 1, 2, \ldots, k).$$

Posons maintenant $n = lm''$, où $l$ est le plus grand diviseur de $n$ premier avec $m$. Nous pouvons supposer que tous les $\alpha_i$ sont divisibles par $l$. En effet, si un certain des nombres $\alpha_i$ n'est pas divisible par $l$, nous déterminons $x$ de la congruence $lx \equiv 1 \pmod{m'}$ et remplaçons $\alpha_i$ par $\alpha_i lx$, car

$$X^{\alpha_i lx} = X_1^{\alpha_i lx} X'^{\alpha_i lx} = X_1^{\alpha_i lx} = X_1^{\alpha_i} \subseteq \mathfrak{M}_i.$$

Les conditions (1) et (2) peuvent être remplacées par les suivantes:

$$X^l = Z, \tag{3}$$

$$Z^{m_3} \subseteq \mathfrak{A}, \tag{4}$$

$$Z^{\beta_i} \subseteq \mathfrak{M}_i \quad (i = 1, 2, \ldots, k), \tag{5}$$

où les nombres $\beta_i$ peuvent être choisis arbitrairement. En effet, si un certain élément $X$ vérifie les conditions (1) et (2), il devra vérifier l'égalité (3) avec les conditions supplémentaires (4) et (5).

Inversement, si $X$ vérifie l'égalité (3) avec les conditions supplémentaires (4) et (5), alors $X$ doit aussi vérifier les conditions (1) et (2).

Désignons par

$$Z_1, Z_2, \ldots, Z_s$$

les éléments $Z$ vérifiant les conditions (4) et (5).

Cherchons à déterminer le nombre des éléments $X$ vérifiant l'une des conditions:

$$X^l = Z_1, X^l = Z_2, \ldots, X^l = Z_s.$$

Il est facile à déduire de (4) et (5) que l'ensemble des éléments $Z_1$, $Z_2, \ldots, Z_s$ présente un complexe invariant d'éléments du groupe $\mathfrak{G}$. Le nombre des éléments $X$ vérifiant les conditions posées sera donc un

multiple de $l$ en vertu du théorème de Frobenius. Le lemme est ainsi démontré.

Maintenant pour démontrer le théorème nous allons appliquer la méthode du crible d'Eratosphène ainsi qu'il a été fait par Turkin dans un cas analogue dans l'article précédemment cité (4) et par l'auteur dans l'article «La généralisation du théorème de Turkin» (5).

Nous nous proposons de déterminer maintenant le nombre des éléments vérifiant les conditions

$$X^n \subseteq \mathfrak{A}, \tag{6}$$

$$X^\alpha \subseteq \mathfrak{M}, \tag{7}$$

où $\alpha$ peut être choisi arbitrairement. Il a déjà été indiqué précédemment qu'on peut sans restreindre la généralité supposer que $\mathfrak{A}$ est une classe d'éléments conjugués.

D'autre part, nous allons considérer le complexe $\mathfrak{M}$ comme formé de $k$ classes d'éléments conjugués: $\mathfrak{M}_1, \mathfrak{M}_2, \ldots, \mathfrak{M}_k$, les ordres des éléments de ces classes étant désignés par $m_1, m_2, \ldots, m_k$ comme dans la démonstration du lemme.

Nous cherchons à déterminer le nombre des éléments dont la $n$-ième puissance appartient à la classe $\mathfrak{A}$ et dont une certaine puissance appartient à l'une au moins des classes $\mathfrak{M}_1, \mathfrak{M}_2, \ldots, \mathfrak{M}_k$.

Introduisons les notations suivantes: le plus grand diviseur du nombre $n$ premier avec $m_i$ sera désigné par $n_i$; le plus grand diviseur du nombre $n$ premier avec le produit $m_i m_j$ sera désigné par $n_{ij} = n_{ji}$ et ainsi de suite. Enfin le plus grand diviseur du nombre $n$ premier avec le produit $m_1 m_2 \ldots m_k$, c'est-à-dire avec $m$, sera désigné par $n_{12\ldots k}$. Le nombre des éléments vérifiant la condition (6) et l'une des conditions

$$X^{\alpha_i} \subseteq \mathfrak{M}_i \tag{8}$$

($\alpha_i$ peut ici être choisi arbitrairement, $i$ est l'un des nombres $1, 2, \ldots, k$) est un multiple de $n_i$ en vertu du lemme.

Désignons ce nombre par $\lambda_i n_i$, où $\lambda_i$ est un certain entier. Le nombre des éléments vérifiant ces conditions est évidemment inférieur à

$$\sum_{i=1}^{k} \lambda_i n_i$$

parce qu'il a des éléments qui vérifient simultanément la condition (6) et au moins deux des conditions (8). Le nombre de ces éléments est égal à

$$\frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \mu_{ij} n_{ij}, \tag{9}$$

où les $\mu_{ij}$ sont des entiers et d'ailleurs $\mu_{ij} = \mu_{ji}$ pour $i \neq j$ et $\mu_{ij} = 0$ pour $i = j$.

La différence

$$\sum_{i=1}^{k} \lambda_i n_i - \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \mu_{ij} n_{ij}$$

est évidemment inférieure au nombre des éléments vérifiant les conditions (6) et (7), car certains éléments sont comptés dans la somme (9)

deux ou plus de deux fois. Ce sont les éléments qui vérifient non seulement la condition (6), mais encore au moins trois des conditions (8).

En continuant ce procédé, nous arrivons enfin à la conclusion que le nombre des éléments vérifiant les conditions du théorème est donné par la somme

$$\sum_{i=1}^{k} \lambda_i n_i - \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \mu_{ij} n_{ij} + \ldots \pm \nu n_{12 \ldots k} \tag{10}$$

où $\nu$ est un nombre entier.

Il est facile à voir que chaque élément du groupe vérifiant les conditions du théorème est compté dans la somme (10) une et une seule fois. Si, par exemple, l'élément considéré vérifie la condition (6) et $s$ des conditions (8), des il est compté

$$C_s^1 - C_s^2 + C_s^3 - \ldots \pm C_s^s = 1 - (i-1)^s = 1$$

fois.

Remarquons enfin que tous les membres de la somme (10) sont divisibles par le plus grand diviseur de $n$ premier avec $m$.

Le théorème est ainsi démontré.

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## LITTÉRATURE CITÉE

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*MATHÉMATIQUES*

# SUR UN CRITÈRE POUR LES GROUPES NON-SIMPLES

Par W. K. TURKIN et P. E. DUBUQUE

*(Présenté par O. J. Schmidt, de l'Académie, le 22.IX.1938)*

Dans son article «Über Herstellung und Anwendungen der monomialen Darstellungen endlicher Gruppen» W. K. Turkin (1) a démontré le théorème suivant:

«Soit $\mathfrak{G}$ un groupe et $\mathfrak{H}$ — son sous-groupe. Soit

$$\mathfrak{G} = \mathfrak{H} + \mathfrak{H}G_2 + \ldots + \mathfrak{H}G_s.$$

Soit $A$ un élément de $\mathfrak{G}$. Soit

$$G_\lambda A = H^{(\lambda)} G_{i_\lambda}$$

(où $H^{(\lambda)}$ est un élément de $\mathfrak{H}$). Si le produit

$$H^{(1)} H^{(2)} \ldots H^{(s)}$$

n'appartient pas à la commutante $\mathfrak{H}$, le groupe $\mathfrak{G}$ possède un diviseur normal».

Dans le cas où le sous-groupe $\mathfrak{H}$ est abélien, il convient de présenter dans une autre forme ce critère pour qu'un groupe fini soit non-simple.

Introduisons les notations suivantes qui ont déjà été employées dans l'article de W. K. Turkin «Quasinormalisateurs et représentations monomiales» (2), ainsi que dant l'article commun des auteurs «Sur la structure des groupes simples» (3).

Soit encore $\mathfrak{H}$ un sous-groupe du groupe $\mathfrak{G}$ et soit $\mathfrak{A}$ un autre sous-groupe du groupe $\mathfrak{G}$ contenant $\mathfrak{H}$. Soit

$$\mathfrak{A} = \mathfrak{H} + \mathfrak{H}\Gamma_2 + \mathfrak{H}\Gamma_3 + \ldots + \mathfrak{H}\Gamma_s.$$

Soit

$$\Gamma_\lambda A = \overline{H}^{(\lambda)} \Gamma_{i_\lambda}$$

($\overline{H}^{(\lambda)}$ est un élément du sous-groupe $\mathfrak{H}$). Nous allons désigner le produit

$$\overline{H}^{(1)} \overline{H}^{(2)} \ldots \overline{H}^{(s)}$$

par

$$\Pi(\mathfrak{A}, A).$$

Démontrons maintenant la proposition suivante.

Théorème. *Soit $A$ un élément d'ordre $n$ du sous-groupe abélien $\mathfrak{H}$ du groupe $\mathfrak{G}$, chaque élément de $\mathfrak{H}$ conjugué à une puissance de $A$ étant encore une puissance de $A$. Soit $n = \prod_{i=1}^{k} p_i$, où tous les $p_i$ sont des nombres premiers et $\mathfrak{N}$ est le plus petit multiple commun des normalisateurs des groupes cycliques $\left\{A^{\frac{n}{p_i}}\right\}$. Si $\Pi(\mathfrak{N}, A)$ n'est pas égal à l'unité, le groupe $\mathfrak{G}$ possède un diviseur normal.*

Pour le cas où $n$ est une puissance d'un nombre premier, ce théorème a été démontré dans l'article précédemment cité (²).

Démonstration. Soit

$$\mathfrak{G} = \mathfrak{H} + \mathfrak{H}G_2 + \ldots + \mathfrak{H}G_s \tag{1}$$

et

$$G_\lambda A = H^{(\lambda)} G_{i_\lambda}, \tag{2}$$

donc

$$\Pi(\mathfrak{G}, A) = H^{(1)} H^{(2)} \ldots H^{(s)}. \tag{3}$$

En vertu de la proposition citée au commencement, si le produit $\Pi(\mathfrak{G}, A)$ n'est pas égal à l'unité, le groupe $\mathfrak{G}$ possède un diviseur normal. Donc, pour démontrer le théorème, il suffit de montrer que l'on a

$$\Pi(\mathfrak{G}, A) = \Pi(\mathfrak{N}, A).$$

En d'autres mots, il suffit de démontrer qu'en calculant les produits (3) il ne faut tenir compte que des facteurs $H^{(i)}$ qui correspondent, au sens de l'égalité (2), aux résidus du développement (1) appartenant au groupe $\mathfrak{N}$.

Supposons qu'un certain résidu du développement (1), soit $G_l$, n'appartient pas au groupe $\mathfrak{N}$. Considérons l'ensemble des éléments

$$G_l, G_l A, G_l A^2, \ldots, G_l A^{n-1}. \tag{4}$$

Il est facile à démontrer que tous les éléments de l'ensemble (4) appartiennent à des systèmes différents du développement (1). En effet, une égalité de la forme

$$G_l A^r = H G_l,$$

où $H$ est un certain élément du groupe $\mathfrak{H}$, entraînerait

$$G_l^{-1} H G_l = A^r;$$

donc, d'après les conditions du théorème l'élément $H$ devrait présenter une certaine puissance de $A$. D'autre part, les éléments transformant une puissance de $A$ en une autre puissance de $A$ constituent le groupe $\mathfrak{N}$, et par hypothèse $G_l$ n'appartient pas à $\mathfrak{N}$.

Donc, nous pouvons considérer les éléments (4) comme résidus des développements (1). En multipliant (à droite) tous les éléments de la suite (4) par $A$, nous obtenons:

$$G_l A, G_l A^2, \ldots, G_l A^n = G_l. \tag{5}$$

L'ensemble des éléments (5) ne diffère de l'ensemble initial (4) que par l'ordre de ses éléments. Ainsi le produit des éléments $H^{(i)}$ correspondant, au sens de l'égalité (2), aux résidus de (4) est égal à l'unité.

Si parmi les résidus du développement (1) de $G_i$ il se trouve un résidu qui n'appartient pas au groupe $\mathfrak{N}$ et n'appartient à aucun des systèmes

$$\mathfrak{H}G_l, \mathfrak{H}G_lA, \mathfrak{H}G_lA^2, \ldots, \mathfrak{H}G_lA^{n-1},$$

il pourra être pris pour point de départ dans la construction d'un nouveau système de résidus tout à fait analogue à (4) et pour lequel les raisonnements précédents seront encore valables.

Nous arrivons enfin à la conclusion que

$$\Pi(\mathfrak{G}, A) = \Pi(\mathfrak{N}, A).$$

Le théorème est ainsi démontré.

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*PHYSICS*

# IONIZATION OF SODIUM ATOMS ON THE SURFACE OF THORIATED TUNGSTEN

By N. D. MORGULIS and B. I. DYATLOVITSKAJA

*(Communicated by A. F. Joffe, Member of the Academy, 27.IX.1938)*

The surface structure of thermoelectronic cathodes covered with active monoatomic films has already been thoroughly studied in many researches, chiefly through their electronic emission. These investigations have led to the important conclusion that the adsorbed atoms in such films are usually distributed over the core surface not in a uniform film, but in isolated patches. As an instance of such researches we may cite the data of investigations of thoriated tungsten (ThW) obtained when studying the anomalous effect of Schottky (1) and applying the electronic microscope (2). While confirming the non-uniformity of the distribution of adsorbed atoms on the surface, these data are of a rather qualitative character and yield no accurate or quantitative results as to the contact properties of such surfaces. In this study the attempt is therefore made to carry the work further in this direction by making use of the phenomenon of thermic ionization of atoms on the surface.

As known from numerous investigations, the coefficient of surface ionization satisfies quite well the equation of Saha-Langmuir (3):

$$\alpha = \frac{I_p}{I_0} = \frac{1}{1 + 2\exp\left[\frac{e}{kT}(V_i - \varphi)\right]} \approx \frac{1}{2}\exp\left[\frac{e}{kT}(\varphi - V_i)\right], \qquad (1)$$

where the last transformation refers to our case of Na—ThW, where $V_i > \varphi$; $V_i$ is the potential of ionization of the atom; $\varphi$ is the work function of the electron. The first attempt to apply equation (1) to ThW led Dobrezow (4) to the conclusion that the phenomenon is conditioned in this case by the local values of the work function $\varphi$ which is, in addition, non-uniformly distributed. The study on the neutralization of potassium and caesium ions and the ionization of K and Cs′ atoms on the ThW surface (5), started but not as yet achieved by us, has also yielded so far a qualitative evidence of the existence of a very considerable contact non-uniformity on the ThW surface.

Let us assume now, as has already been done in the case of the anomalous Schottky (6) effect, that the work function is distributed on the ThW surface in checker-board order, i. e. that it can be expressed by

$$\varphi = \varphi_0 + \frac{1}{2}\Delta V_k \cos\frac{\pi x}{a}\cos\frac{\pi y}{b}. \qquad (2)$$

In this case the real ion current $I_p$ is obtained from (1) by taking the mean of (2) on the surface, i. e.

$$I_p = \bar{\alpha} I_0 = \frac{2I_0}{ab} \int_0^{\frac{a}{2}} \int_0^{b} \alpha(\varphi) dx\, dy = BF(\gamma) \exp\left(\frac{e\varphi_0}{kT}\right), \tag{3}$$

where $\gamma = \frac{e\Delta V_k}{2kT}$ and $F(\gamma) = F\left(\frac{e\Delta V_k}{2kT}\right)$ is a known function ([6]) of the contact difference of the potentials $\Delta V_k = (\varphi_1 - \varphi_2)$ between sections with maximum ($\varphi_1$) and minimum ($\varphi_2$) of the work function. In the same way we obtain for the electronic current:

$$I_e = AF(\gamma) \exp\left(-\frac{e\varphi_0}{kT}\right). \tag{4}$$

From equations (3) and (4) it is possible to find the required values of $\varphi_0$ and $\Delta V_k$ for various degrees of activation $\Theta$ upon measuring $I_p$ and $I_e$ experimentally, since the values $A$ and $B$ can be readily determined.

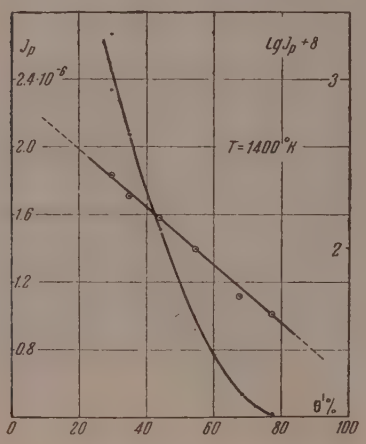


Fig. 1.

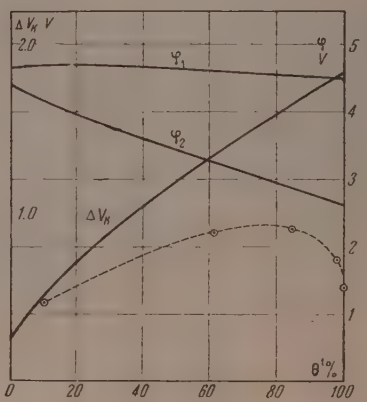


Fig. 2.

The bulbs used by us were, like the preceding ones ([7]), diodes with a filament of thoriated tungsten and an anode having protective rings, with distilled sodium within the bulb. The vapour pressure of sodium was determined from the temperature of the thermostat, into which the lamp was immersed. The results of the $I_p$ measurements for $T = 1400°$K are presented in Fig. 1, and the results of the analysis of these data are given in Fig. 2. Analogous results were obtained both for $T = 1700°$K and for the second, control bulb. The axis of abscissae in Fig. 1 and 2 shows the arbitrary degree of the thorium coating on the tungsten $\Theta_1 = \frac{\log I_\Theta / I_0}{\log I_1 / I_0}$, the relation of which to the real degree of coating $\Theta = \frac{\sigma}{\sigma_1}$ is determined from the data of Langmuir's work ([8]). An analysis of the data obtained by us makes it possible to draw the following preliminary conclusions:

1. On the surface elements corresponding to the maximum of the cosine curve ([2]) the work function $\varphi_1$ changes very little during activation, and conserve a value approaching that of pure tungsten (4.52 eV). Thus, in these

spots, which may have in general an extremely small geometric surface, there is almost no thorium adsorption. On the contrary, adsorption chiefly occurs in the region of sections with a work function $\varphi_2$, where it occurs normally leading to a value of $\varphi_2 \approx 2.6$ eV at $\Theta_1 \approx 1$, i. e. close to the effective value of $\varphi = 2.62$ eV, which is usually obtained from the slope of Richardson's straight line in semilogarithmic scale for a completely activated cathode, since in the latter case its total emission will be practically determined by the emission from areas where thorium is adsorbed.

2. The value of the contact difference of the potentials $\Delta V_k = (\varphi_1 - \varphi_2)$ and its change with $\Theta_1$ (Fig. 2) differs from the one obtained by Becker[6] by analyzing the anomalous Schottky effect (the dotted curve in Fig. 2). The reason of this divergence is difficult to explain; it may possibly be accounted for by the greater accuracy of our method connected with application of ions, having a much shorter phase wave-length $\lambda = \frac{h}{Mu}$ than electrons, thus making it possible to localize the presence of extremely small elements of the surface with pure tungsten [4].

We thus see that the method of surface ionization is very effective when studying film cathodes. The cosine curve distribution approximated by us in the beginning [2] is of course very rough and even to some extent limits further analysis. However, it permits of drawing a number of new conclusions as to the nature of the processes occurring here.

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*PHYSICS*

# THE SECONDARY RADIATION PRODUCED BY THE PENETRATING COMPONENT OF THE COSMIC RAYS

By G. FRANK-KAMENECKIJ

*(Communicated by A. F. Joffe, Member of the Academy, 5. X. 1938)*

As well known, there are two different components of the cosmic radiation—the soft one ($M$) and the penetrating one ($D$). Now particular attention is paid to the investigation of the properties of the penetrating group which is assumed to consist of «heavy electrons». Of particular interest is the question of the creation of showers connected with the penetrating component. One may not doubt that these showers are mainly produced by the secondary electrons created during the interaction between the penetrating particles and the absorbent. It is necessary to assume that the soft component consists of two parts: the primary soft radiation independent of the hard group and the secondary radiation which is in equilibrium with the penetrating component. The question arises as to the relation between the two groups of the soft radiation.

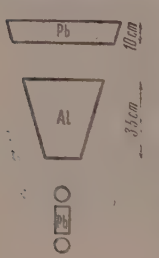


Fig. 1.—Distribution of counters and filters.

It was supposed till now that both components $M$ and $D$ can be regarded as independent. However, this conclusion was based on some indirect and rather qualitative evidence. Recent investigations (1) show that such a hypothesis is difficult to reconcile with the results of the cascade theory of showers. These investigations lead to the assumption that at least a considerable part of the soft component is in equilibrium with the penetrating radiation. Nielsen and Morgan (2) have recently published data of measurements which give direct evidence of this assumption. The question about the mechanism of the creation of secondary electrons lacks definite clearness. It is probable that the creation of these electrons is largely due to $\delta$-rays formation. The amount of electrons in equilibrium can be easily calculated. A definite conclusion can be drawn as to the mass of the primary penetrating particles from the comparison of such calculations with the experimental data.

In connexion with these two questions some measurements were undertaken in order to evaluate the equilibrium intensity of the soft group and its dependence on the atomic number of the absorbent; the Rossi-Auger method was made use of.

A screen of 10 cm lead was placed at a large distance above the two Geiger-Müller counters* (Fig. 1). The screen was totally eliminating the soft

* The counters had brass walls of 0.1—0.12 mm thickness and glass walls 0.5—1.0 mm thick. They were filled with a mixture of air and alcohol vapour.

radiation present in the atmosphere. The absorption curve of the penetrating group, as well as the soft radiation it is accompanied by, could be investigated by placing layers of lead between the two counters (Curve *1*, Fig. 2). The condition of equilibrium in aluminium was in some approximation attained by placing 35 cm aluminium between the set of counters and the lead screen; the same procedure enabled us to investigate the absorption curve (Curve *2*, Fig. 2). Moreover, the absorption curve was obtained without placing any screen above the counters (Curve *3*, Fig. 2). Analyzing the curves obtained, it is possible to distinguish the absorption of the soft and the hard components. The dotted straight lines in Fig. 2 represent the course of absorption of the penetrating component, the absorption coefficient of which is known*.

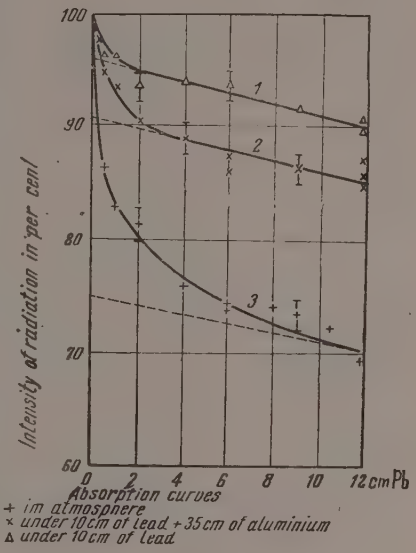


Fig. 2.

The secondary soft radiation was determined (Table 1), making use of such an analysis of the equilibrium intensities**.

The accuracy of the values obtained is rather small because of the inevitably considerable influence of statistical errors. The distribution of the experimental points (Fig. 2) shows that the experimental errors somewhat exceed the statistical fluctuations. This may be obviously due to slight fluctuations of the sensitivity of the counter set. However, the comparison of the curves shows clearly that the equilibrium intensity of the secondary soft group is essentially higher in light substances, than in heavy ones***.

Table 1

| | Atomic number | Intensity of the soft radiation in per cent of the penetrating group |
|---|---|---|
| Lead . . . . . | 82 | 4.5±3 |
| Aluminium . . . . . | 13 | 11 ±3 |
| Atmosphere . . . . . | 7 | 33 ±3 |

* A number of authors give the values of the absorption coefficient of the penetrating component ranging from $4.5 \cdot 10^{-3}$ to $6.5 \cdot 10^{-3}$ $cm^{-1}$ Pb. The value used in this calculation $\mu = 5.7 \cdot 10^{-3}$ $cm^{-1}$ Pb is in the best agreement with our measurements.

** The presence in the strongly absorbed part of radiation in atmosphere of 1—3% of particles with paths exceeding 6 cm lead (Curve *3*, Fig. 2) points to the existence of secondary «semi-heavies».

*** This result coincides with Schindler's early investigation ([3]) of the transition effects with the aid of the ionization chamber.

It must be noted that in the absence of a lead screen between the counters the secondary radiation created in aluminium compensates the absorption in 35 cm aluminium.

The intensity of the secondaries can be directly calculated from the following statement. The energy of the primary particles, transformed in a layer $dx$ into the energy of the secondary equilibrium radiation, should be equal to the ionization losses energy by the secondary, tertiary, etc. particles*.

$$nb = \int_{w_{min}}^{w_{max}} \sigma(w)\, w\, dw, \qquad (1)$$

where $n$ is the number of secondaries, which accompany a penetrating particle; $b$—the ionization losses per unit path; $\sigma(w)$ —the probability of the creation by a primary particle of a secondary with an energy $w$; $w_{min}$—the minimum energy at which the particle is registered; $w_{max}$—the maximum energy which can be transmitted to the secondary. This method of calculation holds true whatever transformations of secondary radiation (multiplicative processes, etc.) take place. The ionization losses (calculated per atom) increase somewhat slower than the atomic number $Z$. The equilibrium intensity for the secondary radiation should, therefore, increase with the atomic number, since it is probable that the effective cross-section (per atom) for the creation of secondaries increases either in proportion to the atomic number or more rapidly.

The expression (1) can be applied to the $\delta$-radiation using the formula for the probability of emission of $\delta$-particles by the «heavy electrons» given by Bhabha [5] (on the basis of Möller's theory):

$$\sigma(w)\, dw = 2\pi a^2 mc^2 N \left[ \frac{\gamma^2}{\gamma^2 - 1} - \frac{w}{w_{max}} + \frac{w^2}{2(\gamma^2 - 1)(Mc^2)^2} \right] \frac{dw}{w^2}, \qquad (2)$$

where $a = \frac{e^2}{mc^2}$; $\gamma = \frac{E + Mc^2}{Mc^2}$; $m$ is the rest mass of electron; $M$—the rest mass of the primary particle; $E$—the kinetic energy of the primary particle; $N$—the number of electrons in 1 cm$^3$.

Upon substitution in (1) we obtain:

$$n = \frac{2\pi a^2 mc^2 N}{b} \left[ \frac{\gamma^2}{\gamma^2 - 1} \lg \frac{w_{max}}{w_{min}} - \frac{w_{max} - w_{min}}{w_{max}} + \frac{w_{max}^2 - w_{min}^2}{4(\gamma^2 - 1)(Mc^2)^2} \right]. \qquad (3)$$

Taking for calculation the value of the mean energy of cosmic ray particles $E = 3 \cdot 10^9$ eV, the value of ionization losses (given by Bhete and Bloch) per 1 cm lead $b = 14$ MV and $w = 10^7$ eV, we obtain the following values of the secondary radiation intensity:

Table 2

Intensities of Secondary Radiation in Lead
(per cent of penetrating particles)**

| Mass of a primary particle in electronic masses . . . | 1 | 100 | 200 | 500 | 1 000 |
|---|---|---|---|---|---|
| Intensity of the secondary radiation, in % . . . . . | 29 | 26 | 21 | 14 | 9 |

* This method was suggested by D. V. Skobelzyn. Later such a method was used by Nordheim [4].

** The figures given in this table are in contradiction with the results of the complicated calculations made by Bhabha, which points to the imperfection of those calculations.

The comparison of the data calculated with the experimental value 4.5% of secondary radiation in lead seems to show that the mass of the penetrating particle has a very large value (of the order of 1000 m)*.

Such inferences, however, seem to lack conclusiveness, the dependence between $n$ and $Z$ being anomalous.

The interpretation of the obtained dependence is very difficult. It may be supposed that the contradiction with the experimental data is caused by some significant anomaly in the absorption mechanism. The scattering in lead may have some influence too, but it is quite improbable that the scattering would give such a considerable effect. One can suppose that this contradiction has its origin in the anomalous absorption of β-rays discovered by Skobelzyn and Stepanova ([8]).

The data obtained do not give the quantitative relation between $n$ and $Z$.

In order to answer the question as to the share of secondaries in the soft component, we have to extrapolate $n = f(Z)$ to $Z = 7$. There is a jump in the value of $n$ in the case of transition from the aluminium to the atmosphere. Therefore one can assume that in the unfiltered radiation there is a great deal of soft rays which are independent of group $D$. It is, however, necessary to take into account that the true value of the intensity $n$ in aluminium can be larger than the measured one. One has to pay attention to two circumstances. First, it may occur that the secondary fails to be registered when passing through both counters simultaneously with the primary. Control observations show that this source of errors can be neglected in the case of lead. But the aluminium screen is much closer to the counters and one can assume that the «divergence» of the secondaries in aluminium is considerably less than in lead. Secondly, it is possible that a 35 cm layer of aluminium is insufficient for the saturation.

According to the direct measurements by Nielsen and Morgan, practically the whole group $M$ proves to consist of secondaries. If this result is true, we may conclude from our data that equilibrium intensity of secondaries in the atmosphere is seven times as great as in lead.

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* Wilson ([6]) and Auger ([7]) attempted to determine by an analogous method the mass of penetrating particles. Wilson's experimental data are in good agreement with ours. Auger obtained values of secondary radiation ranging from 2 to 10% at various depths under the earth.

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*CHEMISTRY*

# THE CONVERSION VELOCITY OF SUPERSATURATED SOLID SOLUTIONS OF MAGNESIUM—ALUMINIUM

By I. I. KORNILOV

*(Communicated by N. S. Kurnakov, Member of the Academy, 16. IX. 1938)*

The equilibrium diagrams of many metallic systems show that one metal can dissolve in another in the solid state in limited quantities. The fact that this solubility varies with temperature makes it possible to obtain supersaturated solid solutions by tempering alloys after heating them to the temperature at which the solid solution becomes homogeneous.

It is well known that such supersaturated unstable solid solutions are capable of precipitating the excess phase from the solid solution. During precipitation under certain temperature conditions there is a marked increase in hardness, which is of great technical importance and is called ageing.

Up till now limited solid solutions were studied only from the point of view of establishing the solubility limits—of equilibrium diagrams and of the ageing of tempered alloys. But it is of interest to study the velocity of the isothermic decomposition of the solid solutions, and establish the relation between the temperature and time elapsed in precipitation of the excess phase from supersaturated solid solutions, as well as the changes which take place thereby in the physico-chemical properties.

As far as we know from publications, there are no works of this kind, excepting those which are connected with the study of ageing process and of the mechanism of the precipitation of a new phase during them.

We made an investigation of the process of excess phase precipitation, using supersaturated solid solutions of magnesium-aluminium alloys, containing 11.9% aluminium. We chose the following isotherms for which to study this process: 350, 300, 250, 150 and 100°. The methods of study were: microstructure and hardness, by transferring the samples right from the solid solution region into the medium of the chosen isotherm, thus eliminating preliminary tempering of the samples in water.

Results of Investigation. Studying the time of the precipitation process at 350°, we established that conversion sets in immediately after the alloy is transferred to this temperature, and if the sample is kept there for 2 minutes, quite a lot of the excess phase precipitates on the borders of the grain. Markedly different resistance to a new etching reagent found by us (1% alcohol solution of aqua regia) enables us to distinguish sharply the quickly-etched precipitated excess phase from the initial solid solution, which the above reagent etches only very weakly.

The longer the sample is kept at this temperature, the more excess phase precipitates; the crystal formation process of the new phase continues toward the interior of the grain and if it is kept long enough, the whole of the microcut surface becomes coated with thin lamellae, which are rounded off in some places in the form of small grains of the new phase.

In spite of the clear-cut evidence to the effect that the excess phase had precipitated, the hardness, measured in relation to the time of conversion, did not show any noticeable deviations, though tending to increase at first, and to decrease towards the end of the conversion process.

The 300° isotherm shows that the excess phase is precipitated in exactly the same way as at 350°, and differs only in that at this temperature the con-

Fig. 1. × 120.

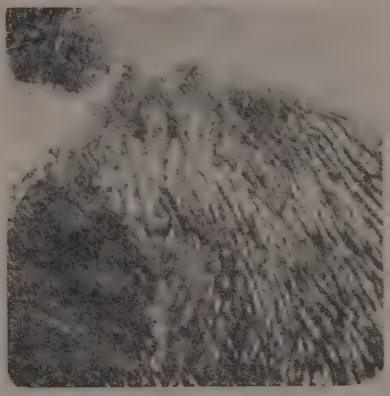

Fig. 2. × 1750.

Etching with 1% alcohol solution of aqua regia.

version process is slower than at 350°. At 350° the precipitation process is completed in 30 minutes, whereas at 300° it takes up to 60 minutes. In this case the hardness markedly increases in the beginning of the conversion, reaches its maximum at the moment of full conversion, and then decreases as the alloy is further kept at this isotherm.

Conversion at 250° is characterized by the fact that the time of full conversion increases and reaches 2 hours. During this time the microstructure changes successively in such a way that the quantity of excess phase precipitated along the borders of the polyhedrons gradually increases, and in the time of full conversion the whole microsurface becomes covered with thin plates of the new phase. The phase precipitated at this temperature is quite a bit thinner than at 350° and 300° and can be distinguished only when greatly magnified. Two microphotographs are given in Figs. 1 and 2; one (Fig. 1) of a microsurface after 15 minutes of conversion, magnified 120 times, the other (Fig. 2) of the same microsurface magnified 1750 times. As we see on the first magnification, the excess phase precipitate is indistinguishable, only the general etched mass is visible on the microphotograph in the places where the solid solution decomposed; on the second magnification one can clearly see the lamellar «perlite» structure of the excess phase, precipitating on the borders of the grain. We obtained structures of a similar nature for all isotherms at which the solid solution decomposes.

The hardness changes in accordance with the conversion process; at the beginning it increases, reaches its maximum at the moment of complete decom-

position of the solid solution and then, if the sample is kept at that temperature any longer, its hardness decreases.

At 200° the conversion time increases still more and, judging by the change in microstructure, complete decomposition takes 5—6 hours. The alteration of microstructure is quite consistent with that of hardness which also changes very regularly: at the beginning it increases, reaches its maximum (which is higher than the maximum hardness for all isotherms) in the time of full conversion and then again tends to decrease, which becomes especially evident when the sample is kept at the isotherm more than 120 hours.

At 150° conversion is considerably slower; after the sample has been kept at this temperature for 1—2 hours, excess phase precipitation cannot yet by fixed. Only after 3—4 hours some precipitation of the new phase could be observed on the borders of the grain, and we were unsuccessful in establishing the end of this process, although we protracted the time of conversion up to 200—240 hours. At the beginning of the process the hardness remains constant, and then as decomposition goes on it gradually increases and reaches a certain maximum. When kept longer, the hardness does note change appreciably.

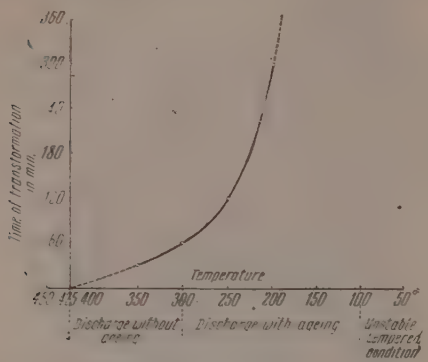


Fig. 3. Time of transformation of supersaturated solid solution as to temperature.

A study of the conversion process at 100° shows that at this temperature the alloy does not show any appreciable changes; after the specimen has been kept at this temperature for 120 hours, the microstructure does not show any visible precipitates neither on the borders of the solid solution polyhedrons, nor inside the grain; only after keeping it for 240 hours at this temperature there appear a few hardly visible thickened lines along the borders of the grain.

At this temperature the hardness also remains constant within the error limits of experiment, showing, however, a slight tendency to increase when the sample it kept long enough. All this shows that at 100° the alloy is tempered, and we get an unstable supersaturated solution which does not change appreciably and consequently does not age within the time scale chosen by us (240 hours).

A study of the microstructure during conversion at all the isotherms shows very definitely that ageing (hardening) goes on as a result of the excess phase being precipitated with a fine crystal structure along the borders of the grain and inside of it, thus confirming the ageing theory of Merica [1] and W. L. Fink and Smith [2,3] which is based upon the precipitation of a finely dispersed supersaturated phase. If the dimensions of the precipitated crystals are larger, the hardness decreases as a result of their coagulating according to temperature and to the time they are kept at this temperature.

On the basis of experimental data obtained from studying the microstructure and hardness we can establish a relation between the velocity or duration of isothermic conversion and the decomposition temperature of the supersaturated solid solution. Fig. 3 gives a diagram which shows the change of full conversion time in relation to the temperature at which the excess phase is precipitated. The co-ordinate origin is taken as the saturation temperature of a solid solution of the chosen alloy which equals 425°; the

temperature is marked off along the abscissa axis, and the full conversion time along the ordinate axis. As the curve shows, the conversion time begins from the zero value at the saturation point, then it gradually increases after the law of exponential curves. The curve begins to go off to infinity at 140—100°. This interval is the temperature at which the excess phase precipitates extremely slowly, but is still accompanied by some rise in hardness if the sample is held out long enough. Below this temperature (100° and lower) the state is of such a nature, that the system can stay in an unstable tempered state without any appreciable conversions or changes in hardness.

The conversion time curve (Fig. 3) makes it possible to divide the temperatures of isothermic conversion schematically into separate regions: 1) the region in which the excess phase precipitates without perceptible ageing, 420—300°, 2) precipitation with ageing, 300—100° and 3) the unstable, tempered state from 100° and lower. These regions show approximately in which of the conversion regions we observe the phenomenon of ageing, and in which of them it is absent either because of a rapid precipitation and enlargement of the precipitated excess phase (upper interval), or because of the tempered state (lower interval).

## Conclusions

1. By studying the isothermic velocity of conversion of supersaturated solid solutions of magnesium-aluminium alloys for all the supersaturation temperature intervals, we established the full conversion time and its relation to the temperature.

2. The saturation point (425°) of a solid solution on the solubility curve corresponds to the zero value of the conversion time curve which, increasing with temperature, goes off into infinity approximately at 140—100°, this being the interval of the unstable, tempered condition of alloys.

3. The curve, showing the change of the conversion time in relation to the temperature, makes it possible to determine the temperature intervals in which the conversion process occurs without ageing, with ageing and where the supersaturated solid solution is in an unstable, tempered state.

4. The change in microstructure showed that the conversion process is heterogeneous, that it begins in all the cases on the borders of the polyhedrons and develops toward the interior of the grain. The hardness changes in accordance with the change in microstructure.

5. These data confirm the theory of hardening during ageing, based on the process of the finely dispersed precipitation of the excess phase.

6. During isothermic conversions in the interval of usual ageing temperatures the hardness goes up parallel with the precipitation of the excess phase and changes so as it does during the ageing process.

7. Bringing about the isothermic precipitations of the excess phase of supersaturated solid solutions without first tempering them in water, makes it possible to decrease the number of thermal operations during ageing and thus reduce the time of thermal treatment. This fact is of great practical interest with regard to the thermal treatment of light alloys.

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*GEOCHEMISTRY*

# CONCERNING THE ACTION OF MINERALS ON GOLD SOLUTIONS

By O. E. ZVIAGINCEV and I. A. PAULSEN

*(Communicated by A. E. Fersman, Member of the Academy, 8. IX. 1938)*

In the oxidation zone of sulphide minerals free sulphuric acid and ferric sulphate may form, and if manganese dioxide and chloric salts are present free chlorine may appear. These substances, especially chlorine, may act as solvents on native gold. The acid gold solutions formed in the oxidation zone will sink down into the layers below where they encounter unoxided sulphide minerals. Here, in the cementation zone, sulphides precipitate the gold. It is hardly of any doubt that such reactions actually take place. However, the equations of these reactions between sulphide minerals and gold chloride solutions have not yet been investigated.

We studied the reactions between gold chloride solutions and galena, sphalerite, chalcopyrite, pyrite and arsenopyrite. Experiments were conducted with gold solutions of definite concentration and minerals of known composition. The products of the reactions were carefully analyzed. The quantitative ratio of elements in the initial and in the reaction products gave the following equations:

a) $3PbS + 2AuCl_3 = 3PbCl_2 + 2Au + 3S$
galena

b) $9FeS_2 + 40AuCl_3 + 6FeCl_3 + 72H_2O = 8FeSO_4 + 7FeCl_2 + 10H_2SO_4 + 40Au + 124HCl$
pyrite

c) $3FeCuS_2 + 7AuCl_3 + 6H_2O = 7Au + 3FeCl_2 + 3CuCl_2 + 1.5H_2SO_4 + 4.5S + 9HCl$
chalcopyrite

d) $7(4ZnS.FeS) + 20AuCl_3 + 10HCl + 26H_2O = 24.5H_2S + 6.5H_2SO_4 + 20Au + 28ZnCl_2 + 7FeCl_2 + 4S$
sphalerite (marmatite)

e) $5FeAsS + 2.5Fe_2O_3 + 20AuCl_3 + 32.5H_2O = 4FeSO_4 + 6FeCl_2 + 20Au + 5H_2AsO_4 + H_2SO + 48HCl$
arsenopyrite

Curiously enough, iron was always reduced to the bivalent in these reactions. The presence of elementary sulphur in the products of the reactions with galena, chalcopyrite and arsenopyrite and of free sulphuric acid in all the reactions except with galena should also be noted.

Along with the reactions between sulphide minerals and gold chloride solution, we conducted the reactions between galena, sphalerite and pyrite and solutions of sodium aurate in the same manner;

f) $3PbS + 8NaAuO_2 + 4NaOH = 8Au + 3Pb(NaO)_2 + 3Na_2SO_4 + H_2O$
galena

g) $1.5(4ZnS.FeS) + 17NaAuO_2 + H_2O = 17Au + 6Zn(OH)_2 + + 1.5Fe(OH)_2 + 6Na_2SO + 1.5S + 5NaOH$
sphalerite (marmatite)

h) $2FeS + 10NaAuO_2 + 4H_2O = 2Fe(OH)_3 + 4Na_2SO_4 + 10Au + 2NaOH$
pyrite

It must, however, at once be stated that though reactions a), b), c), d) and e) are quite probable under natural conditions in the cementation zone, reactions f), g) and h) are of little probability, since $NaAuO_2$ solution is quite unstable under thermal water conditions. According to the data from our experiments, the $NaAuO_2$ solution (0.8 g gold to 100 g solution) had already precipitated more than half of its gold in two hours at 150° in the autoclave.

As has already been shown (1), gold is precipitated by various sulphide minerals at various velocities: galena and sphalerite act very slowly; sulphide containing iron, viz., pyrite, chalcopyrite and arsenopyrite, act quickly. We studied the velocity of gold precipitation by sulphides at various temperatures, various concentrations of gold chloride in the solution and with varied sulphide surfaces. Raising the temperature from room temperature to 65° and 95° greatly increases the velocity at which gold is precipitated by sulphides. Increasing the sulphide surface has the same effect.

The precipitates which gold chloride solution deposits on the sulphides are of various nature, viz., galena becomes coated with a compact gold film; pyrite and arsenopyrite become coated with a crumbly layer of fine, almost colloidal gold.

This nature of precipitation is due to the fact that gold is more inclined to associate with pyrite and arsenopyrite than with sphalerite and galena.

However, the action of minerals on colloidal gold solutions is of an entirely different kind. The nature of the action of minerals on red colloidal gold solution is shown in the table below. For the experiments 50 ml

| Mineral | Test-portion, g | The result of the action of the mineral on 50 ml of red colloidal gold solution (0.673 mg/ml) |
|---|---|---|
| Pyrite | 1 | Turned blue instantaneously; when shaken, all the gold settles in a few minutes |
| Galena | 1 | Turned blue quickly; in 24 hours all the gold settled |
| Chalcopyrite | 1 | Solution turned blue; after boiling and letting stand for 48 hours, all the gold settled |
| Sphalerite | 1 | Solution turned blue with a violet tint; all the gold settled in 24 hours |
| Arsenopyrite | 1 | Solution immediately became violet; no change upon boiling |
| Calcite | 0.5—1 | When weighed-portion is 0.5 part the colour became slightly violet, upon adding mineral up to 1 part and boiling all the gold settled. Precipitate rose-coloured |
| Barite | 0.5—1 | Same as calcite; precipitate blue-violet |
| Quartz | 1 | After boiling and letting stand for 48 hours the solution was rose-violet. After three days part of the gold settled |

of red colloidal solutions (0.673 mg/ml) were taken, together with from 0.5 to 5 g of the mineral, pulverized to 150 mesh. If no noticeable change was observed in the colour of the solution, the solution was boiled together with the mineral (a blind test was always conducted as control).

None of the minerals investigated, including calcite, barite and quartz, was indifferent to the colloidal gold solution. Pyrite precipitates gold the most intensively; next come the sulphide minerals: galena, chalcopyrite, sphalerite and arsenopyrite.

Thermal solutions, carrying gold in rising through veins, encounter[1] such conditions, under which gold deposited from them in a dispersed form ([2]); while washing over sulphide minerals it is precipitated first by pyrite, then by galena and other sulphides, and finally by other minerals.

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*BIOLOGY*

# ON THE STEREOEFFECT OF CRYPTIC COLOUR-PATTERNS IN *LEPIDOPTERA*

By B. N. SCHWANWITSCH

*(Communicated by N. I. Vavilov, Member of the Academy, 14. IX. 1938)*

It is well known that cryptic coloration attains often such a high degree of perfection that its bearers may be practically invisible when in their natural surroundings. After the conclusion of the first classical period in the study of this phenomenon, the work of Thayer ([10]) continued by Süffert ([9]) should be regarded as a most important contribution to the subject.

E. g., in a cryptically coloured bird dark hues of the dorsal side are as a rule followed by some lighter lateral ones which merge gradually into still lighter colours of the ventral surface. A sitting bird is normally lighted from above so that its back surface is lighted at the best, while the ventral one is shaded. A peculiar counteraction of lighting and coloration is thus brought about with the result of the bird looking uniformly coloured all over the body. A further result is that the body loses its solid three-dimensional appearance and seems to be quite flat. The apparent loss of the normal body shape contributes much to the invisibility of the bird among its surroundings This is the essence of the principle of «counter shading» suggested by Thayer on the basis of his investigations of birds and other vertebrates, as well as caterpillars. The latter have been studied from this point of view also by Süffert ([9]) who extended the principle of counter shading on lepidopterous pupae as well.

There is a great number of most perfect cryptic colour-patterns in *Lepidoptera*. However, as the coloration in the latter is mainly that of their generally flat wings, the above principle cannot evidently be applied here. A more or less general opinion is that the wings of moths and butterflies imitate bark, dead leaves and the like. Thayer holds the same view and records, e. g., images of outstanding substances and cast shadows on lepidopterous wings. His relative data are, however, scanty and do not seem conclusive for the problem in question.

The latter may be formulated as follows. Suppose the surfaces of some bodies present in the surrounding to be really reproduced in the wing pattern, and the dependence of the wing upon some micro-landscape can be compared to that of a photograph upon the photographed object. That being so, is it possible to reconstruct by any method the shape and spatial relations of those hypothetical surfaces and bodies, to visualize that imaginary micro-landscape? Common methods of studying cryptic colour-patterns in *Lepidoptera* result in the negative. As a matter of fact it is never possible to decide whether a given stripe or spot stands for an elevation or, on the contrary,

for a depression, and thus the investigation in question cannot be started at all.

Two special methods have been tried to deal with the problem—the method of stereoscopic instruments and that of sculptural models or stereomodels. Several stereoinstruments have been used. A single photograph seen through the so-called «Stereoaufsatz» for the microscope (but without using the microscope, of course) gives a stereoscopic effect, the photograph seems relieved. For the Pigeon's mirror ([3]) stereoscope correct and inverse reprints are made from the same negative and looked at—one through the mirror prism, the other with the naked eye; the image inverted by the prism and that in the naked eye become congruent and a strong stereoeffect is obtained. A single wing suffices to work with the «Stereoaufsatz» and similar devices, while the right and left wings of the same specimen may be used instead of inverted and correct reprints in the mirror stereoscope.

The results obtained by all the above instruments are alike. When examined through one of them a typically cryptic wing offers a remarkable picture. It does not look flat any more, on the contrary, its surface appears quite uneven. Protuberances and depressions of different shape and size are to be seen everywhere, elevated areas cast shadows, and so on. In many species the apparent relief is a very complicated one. May it be considered as corresponding to something real? It has been already noted that common photographs give under the same conditions a normal stereoscopic image without any distortion. If so, the described stereoeffect should be regarded as a sure means to reconstruct the hypothetical uneven surface reproduced in the wing-pattern, say, a depression seen with the aid of a stereoinstrument should correspond to a depression and not to a protuberance in the imaginary micro-landscape. A number of species of *Lepidoptera* belonging to very different groups have been studied by the described method. Many of them have displayed the stereoeffect without any difficulties, some others required modifications in the use of apparatus, and, finally, in a third group, to which the famous *Kallima* belongs, no effect at all has been obtained. As a general rule, dark areas of the colour-pattern look sunken, while light ones seem to protrude. This rule is, however, restricted by a more special one. If between a light *A* (Fig. 1) and dark *B* areas a still darker line *C* passes, the former seems to lie above the latter, so that in a transverse section the spatial relations of the three described components are represented by the line *A'B'C'*. Such a distribution of at least three colours seems to be necessary to bring about the stereoeffect. It has been also observed that the wing-pattern components discovered by the morphological method ([5],[6],[7]) and then studied experimentally ([2],[1],[8]) show often definite «stereocharacters». For example, the so-called medial system of stripes appears mostly as a broad channel-like depression passing across the wing (Fig. 2). The eye-spots sometimes look like very deep and therefore black orifices.

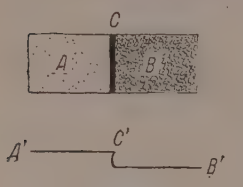

Fig. 1.

The impressions obtained during the described work are so exact and definite that they lead naturally to the idea of a sculptural representation of the relief seen with the stereoapparatus. It proved to be quite possible to make clay «stereomodels» of cryptic colour-patterns. All the most important colour transitions of such complicated patterns as those of, say, *Philosamia cynthia* or *Daphnis nerii*, may be satisfactorily reproduced in non-coloured clay sculptures using no means but carving and modelling.

The total of the material obtained is now in preparation for press. Let us consider here one of the simplest cases of the phenomenon in question.

On the underside of the hind-wing of *Erebia lappona* Esp. (*Rhopalocera, Satyridae*) there may be seen (Fig. 2, *a*), as it has been shown elsewhere (6), the system of two medial stripes ($M^1$, $M^2$), short first discalis ($D^1$), externa ($E^3$) and several dot-like eye-spots (*OC*). When examining this wing with the aid of stereoinstruments, it appears that two zones, one between $M^1$ and $M^2$ and another distal to $E^3$, are lowered compared to the rest of the wing surface. $D^1$ and *OC* seem to be small pits. The above spatial relations

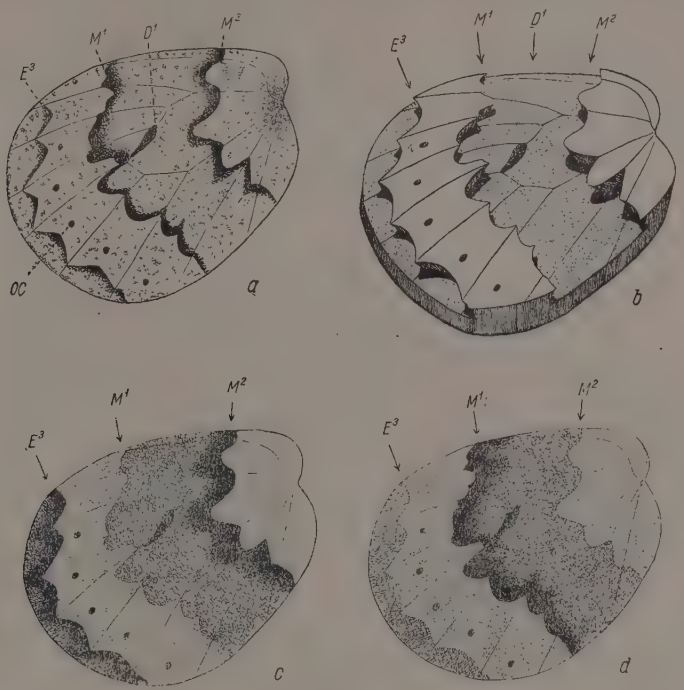


Fig. 2. *a*—colour-pattern seen on the hind-wing underside of *Erebia lappona* Esp.; *b*—stereomodel (see text) of the same lighted anteriorly; *c*—the same lighted from the right; *d*—the same lighted from the left. $E^3$—third externa, $M^1$—first media, $D^1$—first discalis, $M^2$—second media, *OC*—eye-spots.

are reproduced in a model (Fig. 2, *b*) which is somewhat simplified compared to the real pattern, the minute components of the latter not being reproduced. It is easy to see that the shades cast by the higher parts of the model on the lower ones correspond to the stripes of the real wing. The resemblance is, however, inexact if the model is lighted by direct anterior rays and examined from a somewhat posterior point. More resemblance may be obtained when the model is looked at straight from above and lighted with diffuse rays either from the right (Fig. 2,*c*) or from the left (Fig. 2,*d*) which makes prominent either the shades representing $E^3$ and $M^2$, or that corresponding to $M^1$. All the three stripes may be made visible simultaneously under a properly arranged illumination. This effect, however, differs but slighly from Fig. 2,*a* if reproduced by drawing; its photographic representation, though successful, cannot be given in the present paper. Thus, a two-dimensional flat wing-pattern is represented in a non-coloured three-dimensional clay model.

What is the general result of the investigation described? The correctness of the method may be hardly questioned. If in the case of stereoscopic devices the method of stereomodels seems to put all the doubts aside, some optical illusion may possibly be thought of. If we assume all the described data to be erroneous, there are only two alternatives left instead. Either the cryptic colour-patterns do not reproduce any relief at all, the resemblance with the surrounding micro-landscape is restricted to the colours only, and their distribution is merely a random one, or there is some relief reproduced in the pattern which does not correspond to that seen through the stereoscopic devices. It is, however, quite evident that in both cases no construction of satisfactory stereomodels would be possible at all. As far as a non-coloured model leaves no doubt as to what lepidopterous species it is copying, the inadequacy of the said alternatives becomes evident, and thus our main conclusion should be regarded as valid.

We thus see that the old idea of micro-landscape being reproduced in cryptic colour-patterns is corroborated and developed by means of stereomethods. On the other hand, the fact should be emphasized that the distribution of colours in cryptic patterns obeys a definite law, viz., they imitate the distribution of light and shades of some complex relief. This is the very regularity which is responsible for the amazing efficiency of cryptic colour-patterns, so often observed in moths and butterflies. A more general rule involving the phenomenon in question in both birds and *Lepidoptera* may be perhaps expressed as follows. The cryptic colour-pattern results in that convex parts of the animal body appear flat and flat parts look relieved.

If, however, the stereoeffect may be discovered only with the aid of special apparatus, what may be its biological significance? Leaving out of consideration the most complicated problem of binocular vision in birds ([4]) and particularly such in insects, the following circumstance should once more be emphasized. The described regular distribution of colours seems to raise the efficiency of cryptic colour-patterns up to a culmination. If the same colours were distributed at random, the blending with the surroundings would be surely less perfect, and thus the adaptive value of the principle of stereoeffect becomes rather obvious. The structure of cryptic colour-patterns in *Lepidoptera* proves to be more complicated and its dependence upon the surroundings more intimate and exact than it was believed hitherto, and thus one of the fundamental conceptions of the evolutionary theory, that of cryptic coloration, receives in a way more support without any deviation from its main course.

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*PLANT PHYSIOLOGY*

# ON INCREASE OF PERMEABILITY OF PROTOPLASM IN WILTING PLANTS

By N. A. MAXIMOV, Corresponding Member of the Academy

Our knowledge of what is the virtual effect of the injurous action of wilting on plant's cells is still insufficient. We know that the dehydration of cells results in a series of alterations in the normal course of physiological processes: processes of hydrolysis, and of decay in general, become dominant over those of synthesis; growth processes and photosynthesis are checked; there takes place an accelerated ageing of all the cells and tissues in plant, etc. All those questions have lately been treated in detail in a circumstantial work by A. M. Alexeev (1) and there is no need to dwell on them here. Special attention, in our opinion, is due to the phenomenon of after-effect following wilting, since, with normal supply of water being restored, the plant returns to its former state not immediately and a plant which has once suffered wilting is always behind of the growth and yield of the others which have never lacked normal water supply.

The question as to the nature of such a profound action of wilting on all the physiological functions of plant has been engaging my interest for a long time, and I have become gradually convinced that the main responsible cause of the deviation of physiological processes during wilting should be sought in a derangement of the normal state of colloids in the plasm. The abnormal state of colloids should manifest itself with especial clearness in an alteration of the osmotic properties of the plasm, in an increase of the permeability of the latter. As early as in my principal work on freezing away and cold-resistance of plants(2) I gave utterance to my conviction that alteration in the colloidal state of plasm is one of the first manifestations of the action of frost on the cell. This conviction found support later on in the works by S. M. Ivanov (3) and B. M. Golush (4). Starting moreover from this view I professed since long ago, that there is a notable similarity between frost and drought with regard to their action on the cell, I came to the conclusion that in the case of wilting too the protoplasm should respond to the injurious effect by increasing its permeability. To verify this supposition I set up tests to be described, in which I was actively aided by G. S. Soikina, student of the Tashkent University.

The method applied was a most simple one. We cut off leaves from various plants and allowed them to wilt to a different extent on the laboratory table. Then the leaves were immersed in a definite volume of water for 3 hours and the amount of electrolytes washed out of them was estimated. In order to promote diffusion we infiltered the intercellular spaces of the leaves with water by exhausting the air repeatedly.

To restore the leaves from wilting we immersed their petioles in water and then placed the leaves in a moist chamber. The amount of electrolytes washed out of the leaves was estimated after the usual method of solution electric conductivity according to Kohlrausch. In some of the tests we also made use of the leaves from plants suffering a rather deep wilting under the influence of long drought which had been prevailing at Saratov by the end of summer in 1938. We had to perform our experiments in the end of summer, July and August, and therefore the material available for the test was most limited and its choice somewhat occasional. We tried the leaves of wild grape (*Ampelopsis quinquefolia*), cotton and lilac. In all tests we took 1 g of fresh leaf weight per 10 cm³ water.

On account of the space available only part of our results is reported here, and we give only relative figures of the water lost during wilting and of that absorbed on recovering, calculated in per cent to the initial amount of water in the fresh-cut leaves.

Table 1

Experiments with Leaves of Wild Grape

| No | Duration of wilting | Duration of recovering | Loss or increment of water in % | Electric conductivity |
|---|---|---|---|---|
| 1 | Control | — | — | 1.0 |
| | 3 hours | — | —13 | 2.6 |
| | 3 » | 2 hrs 40 m. | + 2.4 | 1.7 |
| 2 | Control | — | — | 1.0 |
| | 17 hours | — | —17 | 2.0 |
| | 17 » | 50 hours | — 2.8 | 1.0 |
| 3 | Control | — | — | 1.0 |
| | 23 hours | — | —61 | 12.5 |
| | 23 » | 23 hours | — 4.6 | 12.5 |

Experiments with wild grape showed that even as little loss of water as 13—17% of its initial content causes the permeability to increase more than twice, while strong dehydration, 60—80% loss, increases the permeability 13 times. Short recovering, during 3 hours, is unable to restore the former low level of permeability even in a slightly wilted leaf (experiment 1), yet after long recovering, for 2 days (experiment 2), the leaves restored their initial state. If, however, wilting had reached a loss of 60% water (experiment 3) no decrease of permeability could be produced even by long recovering. We observed such restoring leaves to turn brown and this was a sign of the dying off of their tissues.

Experiments on cotton have borne out the results obtained with wild grape. Relatively slight wilting produced insignificant and besides reversible increase of permeability in the leaf tissues, whereas deeper wilting resulted in higher increase which would not disappear for a long time. It is worthy to note (experiment 4) that in the leaves restored from short wilting the permeability of protoplasm turned out to have dropped so low as to nearly half of what it was in the initial material. It might possibly be connected with a higher content of water in the leaves restored as compared to fresh-cut controls. And this in turn points to the fact that the plants, when we were cutting leaves from them, already suffered a rather considerable lack of water, and the permeability of their cells was therefore somewhat increased against norm.

Table 2

Experiments with Cotton Leaves

| No | Duration of wilting | Duration of recovering | Loss or increment of water in % | Electric conductivity |
|---|---|---|---|---|
| 4 | Control | — | — | 1 |
| | 3 hours | — | −29 | 1.2 |
| | 3 » | 3 hours | +21 | 0.45 |
| 5 | Control | — | — | 1 |
| | 17 hours | — | −45 | 5.7 |
| | 17 » | 26 hours | +17 | 1.7* |
| | 17 » | 26 » | −11 | 7.2** |

In experiment 5, part of the leaves after 17-hour wilting maintained their life activity while the other died away on recovering. We examined both kinds of leaves separately and found the latter to have not only reduced, but even increased their permeability through recovering, whereas the former had almost quite restored the initial state.

The experiments with lilac brought especially clear-cut evidence of the increase of permeability, due to the action of drought which the plants under experiment were suffering in natural conditions of their habitat. For the experiment we took leaves from the shrubs which were going through different stages of wilting, and estimated their output of electrolytes either immediately after they had been cut off from the shrub, or upon recovering for a long time in a moist chamber, or else efter additional wilting of cut-off leaves in the room.

Table 3

Experiments with Lilac Leaves

| No | Condition of plants | Treatment of plants | Duration | Water content in % of abs. dry weight | Electric conductivity |
|---|---|---|---|---|---|
| 6 | Weak wilting | Fresh-cut leaves | — | 134 | 1 |
| | Strong wilting | Do | — | 80 | 2.5 |
| 7 | Strong wilting | Fresh-cut leaves | — | 87 | 4 |
| | | Restored leaves | 18 hours | 161 | 1 |
| 8 | Weak wilting | Fresh-cut leaves | — | 142 | 4 |
| | | Additional wilting | 14 hours | 72 | 6 |
| | | Restored leaves | 47 » | 184 | 1 |

These experiments have shown that long wilting of the whole shrub under field conditions produces the same increase of permeability in the protoplasm of leaf tissues, as does a wilting of cut-off leaves in the room.

* Restored leaf. ** Leaf died while restoring.

Yet, a sufficiently protracted healing of such leaves in moist chamber makes them to regain the normal permeability.

Our experiments, in spite of their preliminary character, furnish incontrovertible evidence of a quite important fact, in our opinion, viz., that the wilting of plants brings about an increase of permeability in the protoplasm of the cells. A slight and short wilting results thereby in immaterial increase of permeability which easily and rapidly disappears on recovering, while a deep and long wilting urges the permeability to greater and more stable rise from which it can be reduced only very slowly to its former value.

This increase of permeability seems to be one of the very first signs the protoplasm announces the change in the condition of its colloids on dehydration, and I am inclined to consider many other sequels of wilting as resulting from this altered state of colloids. The check of growth processes, the reduced ability to restore turgor and, may be, the relief of the building-up processes by the breaking-down ones have in my opinion their responsible cause in the cell having lost its osmotic properties. Further investigation we are going now to begin has to show in how far these suppositions are right. As the change in cells' permeability to electrolytes contained in the cell sap are rather easy to estimate quantitatively, I believe that with the use of that indicator we can frame a simple and short method to estimate the stability of plants against dehydration. Having now regard to the statement I established many years ago ([5]) that the drought resistance of plants is in the first instance (if not exclusively) determined by their ability to stand out a long dehydration of cells without or with but a little damage, I am quite sure that with such a method at our disposal we shall be essentially helped to solve the difficult problem of comparative estimation of different crop varieties in respect of their drought resistance.

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*PLANT PHYSIOLOGY*

# ROOT FORMATION INDUCED BY HETEROAUXIN IN CUTTINGS OF SUBTROPICAL PLANTS DIFFICULT WITH REGARD TO ROOTING

By N. A. MAXIMOV, Corresponding Member of Academy,
M. M. GOCHOLASHVILI and V. I. TSKHOIDZE

In the previous communication (1) we reported our experiments on heteroauxin induction of rooting in the cuttings of subtropical woods, citrus plants in particular, and described the method we made use of. These experiments had their favourable results in the development of a method (2) now already used in practice, vegetatively to propagate the *Trifoliatae* (pont.), which is a current stock for citrus plants. This success, as well as the works of Soviet (3) and foreign authors, which followed our report, prompted us to go forward with our experiments and in the first instance on such plants as are especially difficult to root. The most important among them is the olive (*Olea europea*) which spreads only by seeds and whose wide cultivation is the next problem facing the subtropical farming in this country. We therefore set before us the task to win rooted cuttings of this most valuable tree, as well as of its near neighbour in the taxonomic classification—*Olea fragrans*, whose flowers are extensively used for aromatization of tea. With the usual methods employed the cuttings of *Olea europea* will not root ot all, while the cuttings of *Olea fragrans* root very slowly and in insufficient number. Several experiments more were concerned with *Pilocarpus pennatifolia*, an important medecinal plant.

The influence of heteroauxin was tested with different concentrations, 1 : 2000 to 1 : 25000, and different intervals of action, 8 to 48 hours. Rooting was done in a hothouse, in a mixture of sand and peat-moss. We refer here to those variants of the experiments which proved most effective under the conditions of the summer and winter of 1938.

From *Olea europea* we succeeded to root only 20% of rootings, the best results being obtained with young shoots of the last growth. Somewhat better proceeded the rooting of *Olea fragrans* when the highest per cent (up to 70%) fell to the share of cuttings taken from younger trees. In the case of *Pilocarpus pennatifolia* the per cent of rooted cuttings amounted to 40. The controls did not root at all in neither of the three plants.

The above experiments on rooting the cuttings of subtropical plants warrant the data of our last years' tests and enable us to consider the heteroauxin treatment as a most effective method vegetatively to propagate those trees which are difficult to root. We, therefore, urge the production of synthetic heteroauxin in this country on a scale which would meet not only with the purposes of the scientific experiment, but also industrial use of this substance.

Rooting of Cuttings of Some Subtropical Plants Induced by Heteroauxin

| | Concentration of heteroauxin | Interval of action in hours | % of cuttings rooted | | | |
|---|---|---|---|---|---|---|
| | | | within 2 months | | within 2½ months | |
| | | | treated with heteroauxin | controls | treated with heteroauxin | controls |
| *Olea europea* . . . . . | 1 : 2000 | 8 | 20 | 0 | — | — |
| *Olea fragrans:* | | | | | | |
| Cuttings from old tree . . | 1 : 5000 | 16 | — | — | 39 | 0 |
| | 1 : 2000 | 24 | — | — | 35 | 0 |
| Cuttings from young tree . | 1 : 5000 | 24 | 40 | 0 | — | — |
| | 1 : 2000 | 24 | 70 | 0 | — | — |
| *Pilocarpus pennatifolia* . . | 1 : 5000 | 24 | — | — | 40 | 0 |

At the same time there arises the question before the investigator why many of the plants will by no means root at one when induced by heteroauxin. In our previous communication we have already pointed out that the reason of this seems to lie in some other substances being produced by the leaves, which are necessary for the roots to form. Lately Went (4) advanced the hypothesis that root-formation is mainly induced by a special substance—rhyzocoline, formed in the leaves, and that auxin and heteroauxin only assist its movement towards the base of the petiole where root-formation is taking place. In this connexion we have set up a number of experiments under controlled conditions with the aim to establish the factor which favours the effect of heteroauxin upon rooting of cuttings. We hope to report the results of those experiments in the nearest future.

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*PLANT PHYSIOLOGY*

# CONCERNING PHYSIOLOGICAL RÔLE OF ELEMENTS INDISPENSABLE FOR PLANTS IN MINUTE AMOUNTS

By A. P. SČERBAKOV

*(Communicated by A. N. Bach, Member of the Academy, 10. IX. 1938)*

What is the physiological rôle of borax, manganese and other fertilizers in plant's life and how great is their influence upon different crops, are problems actually attacked by physiologists ([1],[2]). It is generally conceded now that the plant requires for its normal development more than seven classical elements of nutrition. Experiments have gone so far to prove this statement that further evidence would be superfluous. With water and sand cultures in thoroughly cleaned media, the addition of boron, copper, sodium and other microfertilizers to a normal nutritive solution is indispensable ([3]).

In ([4]) we have described our experiments with flax which, according to its having been grown with or without various microelements, showed a different picture in the assimilation of calcium, magnesium and phosphoric acid and in their distribution in the leaves and stems. The present article is an account of our further experiments which had for object to trace the changes in the nitrogen and phosphorus balance under the influence of the above factors.

We sought thus to answer two questions. How do the microelements act upon plant's ability to take up phosphorus and nitrogen stored in the nutritive medium (the amounts of those elements carried off by the plant)? To what extent the amounts carried off are used by the plant to build up complex organic components?

We experimented with buckwheat (variety Bogatyr) in sand cultures. Seed, harvested in 1932, were supplied by Shatilovskaya test-station. The experiment was carried on in 1934 in the experimental field of the Scientific Institute for Fertilizers. The sand was thoroughly washed with acid and with distilled water.

The scheme of the experiment was very simple. Full Hellriegel's medium served as control. Alongside of it there was a set of plants given microelements. In other series the dose of P (resp. N or P+N) was only half, and there were also parallel sets with the microelements introduced in solution into the vessels.

Scheme of Experiment

Series I. Hellriegel's medium (full dose of N and P) with and without microelements
» II. » » ($^1/_2$ N) with and without microelements
» III. » » ($^1/_2$ P) » » » »
» IV. » » ($^1/_2$ N+$^1/_2$ P) » » »

With reduced dosage of nitrogen and phosphorus, the components eliminated from culture solution, viz., calcium and potassium, were compensated by equivalent amounts of $CaSO_4$ and KCl.

The amount of microelements added was half that proposed by Sommer and Lipman (5):

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| B—0.25 | mg | per | kg | of | sand, | introduced | as | $H_3BO_3$ |
| J—0.125 | » | » | » | » | » | » | » | KJ |
| F—0.125 | » | » | » | » | » | » | » | NaF |
| Mn—0.75 | » | » | » | » | » | » | » | $MnCl_2$ |
| Cu—0.063 | » | » | » | » | » | » | » | $CuSO_4$ |
| Zn—0.25 | » | » | » | » | » | » | » | $ZnSO_4$ |
| Al—0.25 | » | » | » | » | » | » | » | $Al_2(SO_4)_3$ |

The experiments were carried on in small glass vessels of 1.1 kg sand capacity. The seeds were planted on 11th of June and on 14th and 15th the seedlings appeared at once in all the vessels. Several days later, however, the plants given microelements were found to be ahead of the development of the others, and soit was up the end of the experiment. Flowering was going on normally. It lasted longer in the plants supplied with the microelements. Harvesting was done on August 31. Total nitrogen and phosphorus, protein nitrogen and the phosphorus soluble in the water acidulated with acetic acid, were estimated in the harvested green bulk and seed separately.

The data obtained (Table 1) fell in line with our prospect. In all the sets with the microelements the yield both of green bulk and seed was respectively higher. The favourable effect of microelements was especially conspicuous in the yield of seed. Even with half an amount of nitrogen and phosphorus in the culture solution, the yield of seed was greater than or equal to that obtained with full dose of nitrogen and phosphorus but without microelements. The microelements have more than once been observed to favour the yield (6,7).

Table 1

Yield Data (average from two vessels)

| Scheme | Height of plants in cm per vessel | % | Green bulk in g per vessel | % | Seed bulk in g per vessel | % | Total yield in g per vessel | % |
|---|---|---|---|---|---|---|---|---|
| Series I, NPK . . | 47.5 | 100.0 | 5.5 | 100.0 | 2.85 | 100.0 | 8.35 | 100.0 |
| » NPK+microelem. . . . | 61.0 | 128.4 | 7.2 | 130.9 | 4.1 | 143.9 | 11.3 | 135.3 |
| Series II, $^1/_2$ N+PK | 31.5 | 66.3 | 3.8 | 69.1 | 0.8 | 28.1 | 4.6 | 55.1 |
| » $^1/_2$ N+PK+microelem. . | 43.2 | 95.2 | 5.6 | 102.0 | 2.6 | 91.2 | 8.1 | 97.0 |
| Series III, $^1/_2$ P+ +NK . . . | 32.5 | 68.4 | 5.0 | 90.9 | 1.53 | 53.7 | 6.53 | 78.2 |
| » $^1/_2$ P+NK+ +microelem. . | 42.2 | 88.8 | 9.8 | 141.8 | 3.5 | 122.8 | 11.3 | 135.3 |
| Series IV, $^1/_2$ P+ +$^1/_2$ N+K . | 27.9 | 58.7 | 4.3 | 78.2 | 1.1 | 31.6 | 5.4 | 64.6 |
| » $^1/_2$ P+$^1/_2$ N+ +K+ +microelem. . | 45.7 | 95.4 | 5.8 | 105.5 | 3.6 | 126.3 | 9.4 | 112.5 |

As we have mentioned above, the yield obtained was subjected to chemical analysis. In contradistinction to our previous experiments with flax (4)

and those of some other authors (9), we have found the ratio of total phosphorus in both greens and seed to be but slightly affected by the microelements. A marked effect of the latter on the ratio of total phosphorus in the green bulk was observed in only one case, viz., in the series II with reduced content of nitrogen in the culture solution.

Notable change of the ratio of total nitrogen was found to take place in plants given microelements. This ratio increased in the seed and dropped in the green bulk.

In that regard an especially conspicuous example is furnished by the series II and III where, in spite of the reduced content of nitrogen and phosphorus in the culture solution, the addition of microelements caused the ratio of total nitrogen in the seed (resp. in the greens) to increase (resp. to decrease) considerably as compared to the control set (series I without microelements).

As seen from Table 2, the content of protein nitrogen in both seed and green bulk is strictly connected with the presence of microelements in the culture solution. If the ratio of protein nitrogen to total nitrogen content be calculated, it will prove very high in all the cases when microelements had been given to the plants.

Those facts allow us to suppose that in the presence of microelements the nitrogen entering the plant from the nutritive medium is rapidly and almost entirely synthesized to proteins

Table 2

Content of Nitrogen and Phosphorus in the Seed and Green Bulk of Buckwheat (in % of dry weight)

| Scheme | Seed | | | | | | Green bulk | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | Protein N | Ratio of protein N to total N | Total $P_2O_5$ | Soluble $P_2O_5$ | Ratio of soluble $P_2O_5$ to total $P_2O_5$ | Total N | Protein N | Ratio of protein N to total N | Total $P_2O_5$ | Soluble $P_2O_5$ | Ratio of soluble $P_2O_5$ to total $P_2O_5$ |
| Series I, NPK | 1.44 | 1.22 | 84.7 | 0.52 | 0.30 | 57.7 | 1.35 | 0.68 | 50.0 | 0.57 | 0.35 | 61.4 |
| » NPK + microelements | 1.91 | 1.72 | 90.1 | 0.50 | 0.24 | 48.0 | 0.98 | 0.85 | 86.7 | 0.59 | 0.30 | 50.8 |
| Series II, $^1/_2$ N+PK | 1.35 | 1.05 | 77.7 | 0.58 | 0.36 | 62.1 | 1.03 | 0.30 | 29.1 | 0.78 | 0.49 | 62.0 |
| » $^1/_2$ N + PK+microelem. | 1.57 | 1.44 | 91.7 | 0.56 | 0.28 | 50.0 | 0.80 | 0.70 | 83.3 | 0.60 | 0.30 | 50.0 |
| Series III, $^1/_2$ P+NK | 1.30 | 1.02 | 78.2 | 0.51 | 0.39 | 76.5 | 1.21 | 0.40 | 30.0 | 0.50 | 0.36 | 72.0 |
| » $^1/_2$ P+NK+microelem. | 1.59 | 1.47 | 92.5 | 0.51 | 0.26 | 50.9 | 0.89 | 0.82 | 91.1 | 0.51 | 0.27 | 52.4 |
| Series IV, $^1/_2$ N+$^1/_2$ P+K | 1.25 | 0.96 | 76.8 | 0.56 | 0.40 | 71.4 | 1.05 | 0.25 | 25.0 | 0.50 | 0.34 | 66.3 |
| » $^1/_2$ N+$^1/_2$ P+K+microelem. | 1.60 | 1.42 | 88.8 | 0.59 | 0.31 | 52.5 | 0.80 | 0.79 | 94.3 | 0.50 | 0.22 | 63.7 |

both in the green bulk and seed, which is not, however, the case when there are no microelements in the culture solution. The green bulk of plants grown with reduced supply of nitrogen and phosphorus showed an especially poor formation of proteins in the absence of microelements. Similar phenomenon has been observed by Shevchuk in potato (1). In this connexion the following suggestion may gain ground.

As seen from Table 2, the deficient supply with phosphorus and nitrogen in the absence of microelements strongly affects the protein ratio in the green bulk. This fact may serve to estimate the need of a given plant in nitrogen and phosphorus by the method of vacuum infiltration (8) which now enjoys a continually growing application in the works of physiologists. This question, however, will be proved in our further researches.

Another curious phenomenon we can point out here is the fact that the reduced ratio of nitrogen, phosphorus or both of these elements together produced no influence whatever on the content of protein nitrogen in the green bulk and seed of buckwheat when microelements were present in the culture solution. This seems a manifestation of one of the specific features in the physiological action of the microelements—their ability to promote synthetic processes in the plant.

As to the soluble nitrogen, its ratio both in the seed and green bulk was always markedly reduced when the plants were given microelements. Though no direct estimation of the organic forms of the phosphorus has been made, we still believe, from the analytical data at our disposal, that microelements affect the storing up of those forms. Since only a small quantity of phosphorus passed to a water extract weakly acidulated by acetic acid* from the plants grown in the presence of microelements, we may suppose that the inorganic phosphorus turned into some more stable form with regard to the above solvent. It would be hardly justifiable to believe that this form should or could have been of inorganic nature.

We have thus received a rather definite answer to the question we had to solve. The microelements favour the utilization of mineral nitrogen and phosphorus in the plant by turning them into organic forms. The inorganic part of those elements becomes markedly reduced, while the organic one goes up if the microelements are present in the culture solution. The synthetic processes seem thereby to receive a notable acceleration which fact is partly supported by the yield data, showing a notable increase of the green bulk and especially of seed in the presence of microelements.

The second part of our problem has been solved too. The results obtained are in full agreement with the literary indications. As early as in the work by Smirnov (10), there was noticed an enhanced carrying off of nitrogen by tobacco in the presence of boron. Later on the same phenomenon was reported by Shestakov and Shvindenkov (9) with regard to phosphoric acid.

From Table 3 it may be seen that in all cases when the plants had been given microelements added to Hellriegel's medium, they turned to account (carried off) more nitrogen and phosphorus from the culture solution. Special interest is thereby due to the fact that even with reduced store of those nutritive elements in the culture solution (series II, III and IV) they were to highest extent (up to 100% in some cases) used by the plant to build up the yield.

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* To be sure, there passed a series of organo-phosphoric compounds to the extract: phytin, mono- and di-phosphates of glucose, phosphoro-nucleic groups and some others.

Table 3

Ratio (in %) of Nitrogen and Phosphorus Used (Carried off) by Plants from Culture Solution

| | N | $P_2O_5$ |
|---|---|---|
| Series I, NPK | 77.3 | 54.0 |
| » NPK+microelem. | 92.7 | 73.9 |
| Series II, $^1/_2$ N+PK | 62.0 | 40.0 |
| » $^1/_2$ N+PK+microelem. | 100.0 | 51.8 |
| Series III, $^1/_2$ P+NK | 53.7 | 76.7 |
| » $^1/_2$ P+NK+microelem. | 84.0 | 68.1 |
| Series IV, $^1/_2$ N+$^1/_2$ P+K | 78.7 | 65.7 |
| » $^1/_2$ N+$^1/_2$ P+K+microelem. | 100.0 | 100.0 |

## Conclusions

1. The experiments were carried out with buckwheat grown in sand cultures and supplied with different doses of nitrogen and phosphorus in Hellriegel's medium, with and without addition of microelements.

2. The addition of microelements favoured the development and yield both with full and half supply of nitrogen and phosphorus.

3. The microelements being added to the culture solution, the ratio of total nitrogen dropped in the green bulk while it increased in the seed. The ratio of protein nitrogen was enhanced in both cases. No marked change of phosphorus ratio was observed. The ratio of the phosphorus soluble in the water acidulated by acetic acid decreased under the influence of microelements.

4. The microelements induce the plant better to use the mineral nitrogen and phosphorus for the building up of organic forms of those elements.

5. The plants given microelements avail themselves in more plentiful way of the nitrogen and phosphorus stored in the culture solution.

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*PLANT PHYSIOLOGY*

# EFFECT OF INORGANIC PHOSPHATES ON THE FORMATION OF CITRIC, GLUCONIC AND OXALIC ACIDS IN *ASPERGILLUS NIGER*

By SERGIUS LVOFF and E. L. LIMBERG

*(Communicated by A. A. Richter, Member of the Academy, 13. IX. 1938)*

Gluconic acid is formed from glucose by means of direct oxidation of aldehyde into carboxyl group, this reaction being brought about with the aid of a specific ferment isolated from the mould fungus by D. Müller (9) and given by the latter the name of glucoxidase. Gluconic acid can be produced directly neither from fructose, nor from other sugars except from glucose. Citric acid is formed at the expense either of all those sugars which constitute the substratum of alcohol fermentation (glucose, fructose, mannose, saccharose) or of the simpler substances of the $C_3$-series (glycerine, glycerose) which may be considered as fermentation products.

The question of the chimism of citric acid formation gave rise to an animated discussion, that has been taking place during many years between the adherents of two main theories: of fermentation and of direct oxidation. According to the first of them, the molecules of sugar under the influence of ferments first break up into simple compounds, after which these latter by means of synthetic reactions, accompanied by oxidation, give rise to the formation of organic acids both of the $C_4$-series (succinic, fumaric, malic acids and others) and of the $C_6$-series (citric, glutaric, aconitic acids, a. s. o.). Attributing a common origin to the whole complex of organic acids met with in plants, this theory can thus be considered in this respect asaunification theory.

The acids of the $C_4$- and $C_6$-group, as for instance malic and citric acids, are frequently also met together in higher plants (in fruits and leaves) and very likely are of common origin.

The recent investigations of Szent-Györgyi (10) and Krebs (6) present a strong argument in favour of the common origin of the acids of the $C_4$- and $C_6$-series. These authors have shown that the formation of organic acids is linked with the process of fermentation and oxidizing break-up of carbohydrates in animal tissues. According to Kreb's evidence, the acids of the $C_4$- and $C_6$-series intimately participate in the process of oxidation of intermediate products obtained as a result of the fermentative break-up of carbohydrates, while the acids of the $C_6$-series, beginning with citric acid, gradually simplified to the acids of the $C_4$-series. The latter, reacting with fermentation products and getting enriched on their account in carbon atoms, become anew transformed into citric acid, as the initial stage of these cyclic transformation.

True enough, Breusch [1] objects against this theory of cycles, although he does not deny the main fact—that of the stimulating effect of organic acids on the break-up of carbohydrates in animal tissues. The theory of direct oxidation that has been energetically supported during many years by W. S. Butkevich denies any connexion between citric acid and the acids of the $C_4$-series, pointing to some similarity between the citric and gluconic acids as regards the character of their formation. The processes of fermentative break-up, taking place in the mould fungi, have, according to Butkevich, nothing to do with the formation of citric acid which is produced through direct oxidation of the whole molecule of hexose, in combination with some transformations within the latter. The adherents of the theory of direct oxidation, among other arguments against the fermentation theory, point first of all to those contradictions which arise within the fermentation theory itself [the discrepancy between the yield of citric acid and the amount of sugar consumed; the discordance between the yield of citric acid and the amount of $CO_2$ given off [2,8,11]]. A brief surway and analysis of the criticism of the fermentation theory has been given in two articles by one of the authors of the present paper [7,8]. Suffice it to note here that the validity of these arguments has been materially degraded by the recent works by Butkevich [3] himself, who has shown that the formation of citric and other acids in the mould fungi does not proceed directly at the expense of the substratum, but at the expense of the substances previously assimilated by the fungi mycelium from the external medium. In other words, taking into account the balance of citric acid formation, we at the same time judge of the balance of those unknown reactions which make up the assimilation process. Under such complicated conditions it can hardly be expected to obtain exact stechiometric correlations between the products of the single reaction we are interested in.

The discrepancy between these two theories comes essentially to the question, whether or not the fermentation mechanism is involved in citric acid formation of the mould fungi. The formation of gluconic acid does not require the presence of such a mechanism. Is the behaviour of citric acid similar in this respect?

To throw light upon this subject, we set ourselves the purpose to trace the influence of various fermentative factors upon the accumulation of acids that are produced by mould, and, first of all, upon citric and gluconic acid accumulation.

For the present work we chose phosphates which, as it is well known, stimulate the process of fermentation. We used for our experiments the variety of *Aspergillus niger* which is employed for the production of the citric acid at the factory in Leningrad. Under films of the fungus previously grown on a usual nutritive medium, were introduced 100 cm³ of 20% saccharose solution (control) and of the same saccharose additioned with inorganic phosphate ($KH_2PO_4$), the concentrations being 0.5, 0.75 and 1% respectively for different experiments. The flasks were kept in a thermostat at the temperature of 30—32°. At intervals of time which differed as to the experiment, we determined the dry weight of the film, residual sugar (after Bertrand's method), total acidity (by means of titration), and estimated the amounts of citric, gluconic and oxalic acids by the method of Butkevich. The results obtained being similar, we do not describe each experiment separately, giving instead cumulative tables, in which experiments of the same duration and involving identical concentrations of phosphates are summed up. Thus, we carried out four experiments which lasted 24 hours each using 0.5% phosphates. Respective figures in this table express the total of four mean values obtained from each of these experiments.

Cumulative Table of 28 Experiments

| Time of exp. in hours | Concentration of phosphates | Number of exp. | Sugar consumed in g | | Difference in % | Total acidity in cm³ of $\frac{n}{10}$ of alkali | | Difference in % | Oxalic acid found in g | | Difference in % | Citric acid found in g | | Difference in % | Number of exp. | Gluconic acid found in g | | Difference in % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | without phosph. | with phosph. | | without phosph. | with phosph. | | without phosph. | with phosph. | | without phosph. | with phosph. | | | without phosph. | with phosph. | |
| 12 | 0.5 | 4 | 15.58 | 20.26 | +30 | 1 559.3 | 2 049.1 | +31 | 0.55 | 0.54 | −2 | 5.23 | 9.63 | +84 | 4 | 7.67 | 7.04 | − 8.3 |
| 24 | 0.5 | 4 | 19.34 | 22.87 | +18 | 1 826.5 | 2 204.6 | +21 | 0.36 | 0.45 | +24 | 6.30 | 10.18 | +60 | 4 | 6.48 | 6.52 | + 0.6 |
| 24 | 0.75 | 4 | 20.72 | 24.06 | +16 | 2 102.0 | 2 599.5 | +24 | 0.77 | 0.60 | −23 | 8.28 | 12.66 | +53 | 3 | 6.21 | 5.88 | − 5.3 |
| 24 | 1.0 | 2 | 6.32 | 8.0 | +27 | 872.9 | 913.0 | + 5 | 0.50 | 0.18 | −63 | 3.35 | 5.64 | +68 | — | — | — | — |
| 36 | 0.5 | 4 | 39.49 | 43.13 | + 9 | 3 239.0 | 3 804.3 | +17 | 0.43 | 0.96 | +122 | 12.95 | 16.57 | +28 | 4 | 7.23 | 7.48 | + 3.5 |
| 48 | 0.5 | 1 | 8.65 | 10.75 | +24 | 667.5 | 886.2 | +33 | 0.36 | 0.54 | +50 | 2.55 | 3.23 | +27 | 1 | 3.52 | 3.10 | −11.9 |
| 48 | 0.75 | 3 | 27.90 | 32.05 | +15 | 2 285.8 | 3 247.7 | +42 | 0.43 | 0.93 | +117 | 10.31 | 13.85 | +34 | 2 | 5.84 | 5.43 | − 7.0 |
| 48 | 1.0 | 1 | 7.80 | 7.30 | − 6 | 705.0 | 755.0 | + 7 | 0.09 | 01.3 | +250 | 2.85 | 3.17 | +11 | 1 | 3.16 | 2.55 | −19.3 |
| 72 | 0.5 | 1 | 9.60 | 11.20 | +17 | 690.0 | 907.5 | +31 | 0.39 | 0.63 | +61 | 2.36 | 3.27 | +38 | 1 | 3.57 | 2.27 | −36.4 |
| 72 | 0.75 | 2 | 27.90 | 31.72 | +14 | 1 842.4 | 2 493.8 | +35 | 0.33 | 0.92 | +179 | 7.36 | 9.69 | +32 | 1 | 8.10 | 5.95 | −26.5 |
| 72 | 1.0 | 1 | 12.50 | 12.25 | − 2 | 1 112.5 | 1 173.7 | + 6 | 0.20 | 0.39 | +97 | 4.90 | 5.25 | + 7 | 1 | 3.92 | 3.42 | −12.8 |
| 84 | 0.5 | 1 | 15.95 | 15.60 | − 2 | 1 485.8 | 1 331.3 | − 8 | 0.17 | 0.29 | +71 | 6.28 | 5.59 | −11 | 1 | 1.55 | 1.50 | − 3.2 |
| Total | | 28 | 211.75 | 239.19 | +13 | 18 388.7 | 22 365.7 | +21.6 | 4.58 | 6.75 | +47.4 | 72.72 | 98.73 | +35.8 | 23 | 57.25 | 51.14 | −10.7 |

Note. Out of 28 experiments carried out, the analyses of gluconic acid could be realized in 23 only.

As it may be seen from the numeric data of the table, the presence of phosphates results in a considerably higher consumption of sugars, and particularly so during the first time (12—24 hours) of the experiment, when the difference attains its maximum (27 and 30%).

Later on the absolute difference increases but slightly, while the ratio is reduced. This closely resembles the action of phosphates on sugar consumption in the case of yeast fermentation. The highest concentration of phosphates (1%) proved to be superoptimal; during the first 24 hours it produced a strong stimulation (27%), but further on this effect rapidly slackened and became negative. In total, the consumption of sugar in all the 28 experiments increased in the presence of phosphates by 27.44 g, or by 13% against the control.

An analogous stimulating effect was observed with regard to total acid accumulation.

The addition of phosphates in all the experiments (except the last and most prolonged) considerably intensified the accumulation of acid. The total stimulation effect for all the 28 experiments amounts to 3977 $cm^3$ of $\frac{n}{10}$ of acid, or 21.6% of the control. As we are going to see, however, the rôle played by different acids in the production of this effect is far from being identical.

The total production of citric acid in the 28 experiments increased by 26.01 g, or 35.8% of the control, i. e. considerably more than the total acidity (21.6%). This stimulating effect of phosphates affects first of all citric acid. It is particularly pronounced during the first hours of the experiment (12—36 hours), noticeably dropping later on, like the «outburst» which may be observed in the case of the action of phosphates upon alcoholic fermentation. Quite different is the behaviour of gluconic acid, phosphates exerting no stimulating effect upon its formation. Contrarily, in the presence of phosphates its production is somewhat reduced. Gluconic and citric acids are materially different in this respect which points to an entirely different character of the reactions by means of which the accumulation of the above acids is brought about. The reaction of direct oxidation does not require the aid of the fermentation apparatus, and we see that gluconic acid does not respond at all to the presence of phosphates. An opposite behaviour of citric acid shows that phosphates play in this case the part of a fermentative factor, its formation proceeding not through direct oxidation of the glucose molecule, but by means of the reactions of fermentative break-up stimulated by phosphates.

Rather peculiar is the way oxalic acid is influenced by the phosphates. The production of oxalic acid being scanty, the figures are rather small and show considerable variations from experiment to experiment. It may be seen from the table, however, that phosphates act positively upon the formation of oxalic acid, although this action is somewhat delayed as compared to citric acid. The maximum effect for the citric acid corresponded mainly to the first days of the experiments, while for oxalic acid during the first days prevails a negative, though insignificant, effect, the positive influence of phosphates being chiefly displayed on the second and third days, when their action with regard to citric acid is already markedly weakened. Very likely, a competition takes place in this case between citric and oxalic acids on account of phosphates. At all event it is quite doubtless that phosphates act in a stimulating way with regard to oxalic acid as well.

Among these three main acids produced by *Aspergillus niger* we must therefore acutely discriminate gluconic acid from both citric and oxalic ones. This opposition fully agrees with the requirements of the theory of fermentation, according to which not the gluconic acid but the two latter ones

are involved in fermentative reactions. We will not cite here the data on dry weight of the fungus films which in all the experiments with solutions showed a marked increment, as compared with the initial weight, and was particularly high in the presence of phosphates (in average 28%). We have conducted later on a series of experiments with arsenates, believing that the latter would produce in the presence of phosphates an additional effect. Various concentrations were tried, but we failed to obtain a definite positive effect. Live yeast are also known to give no response to the addition of arsenates. Harden [4] believes that this fact is accounted for by the presence in live yeast of sufficient amounts of its own stimulator, performing the same function as arsenates, but being destroyed during the production of yeast preparations. That is why arsenates produce their action not upon living yeast, but only upon yeast preparations. The living mycelium of *Aspergillus*, probably, resembles yeast in this respect producing no effect with arsenates. A special experiment with salts of $KH_2PO_4$, $NaH_2PO_4$ and KCl showed that the effect observed was caused by the action of phosphate anion, and not of potassium cation.

## Conclusions

1. Inorganic phosphates, introduced with sugar solution under the film of *Aspergillus niger*, cause a more intensive consumption of sugar (an average increase by 13%, in some experiments up to 30%) and an increase in total acidity (by 24.6% in average, amounting to 42% in some experiments).

2. This increase in acidity is due in the first place to the stimulating action of phosphates on citric acid formation (by 35.8% in average, amounting to 84% in some experiments).

3. Intensive accumulation of citric acid is observed mainly at the beginning of the experiments (during the first 24 hours), resembling, though in a less distinct form, the outburst of yeast fermentation under the influence of phosphates.

4. No additional effect of the introduction of arsenates could be observed.

5. Phosphates produce a stimulating effect aside from citric acid also upon oxalic acid, the effect being somewhat delayed in the latter case.

6. Phosphates, in contradistinction to the two other acids, produce no stimulation as regards the formation of gluconic acid, its yield being, on the contrary, somewhat reduced in their presence.

7. As phosphates present one of the most important factors of fermentation, such a different response of those acids makes us conclude that citric and oxalic acids require for their formation the aid of the fermentative apparatus, while gluconic acid is formed through direct oxidation.

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*PLANT ECOLOGY*

# ECOLOGICAL AND GEOGRAPHICAL CLASSIFICATION AND EVOLUTION OF BEANS (*VICIA FABA* L.)

By V. S. MURATOVA

(*Communicated by N. I. Vavilov, Member of the Academy, 26 VIII. 1935.*)

Genus *Vicia*, to which the beans refer, is remarkable for its polymorphism and extremely wide habitat. Spreading chiefly over the temperate zone of the Old and New World, it reaches as far as to 67—69° 30′ on the North and 42° on the South (Chile). In this genus *V. faba* occupies a somewhat isolated place. The position of the ovules in the free end of the seed, small terminal points instead of the pendent ovules in vetch, an upright and strong stem, large and flat-sided seeds, etc., all those peculiar characteristics cause us to place this species in a particular section and gave rise to former investigators for isolating it as a separate genus *Faba*.

All the data available point to the culture of beans having originated and developed in the region bordered by Atlantic Ocean on the West and Himalaya mountains on the East. This region includes the habitats of *V. galilaea* (Trab.) Mur.[1] and *V. narbonnensis* L. which are wild relatives of the beans. There too, we find concentrated the greatest number (up to 100) of species of genus *Vicia* in their most diverse forms. The formation and differentiation of the species *V. faba* should have been taking place first of all in south-western Asia where one may now observe the greatest diversity of its forms. Western Mediterranean has been a centre of the formation and development of a younger large-seed group. From there beans penetrated to Europe, USSR and other countries, where they were spread by agriculture.

The habitat of cultivated beans stretches from California eastwards through the corresponding countries of Old and New World up to Japanese archipelago inclusively[2]. Beans are cultivated not only in plain localities, but in mountains as well and attain an elevation of 3000 m in Abyssinia and Afghanistan, and 4200 m in Central Asia. On the North the boundary of bean cultivation meets with the 60° parallel.

The most characteristic feature of *V. faba* is its exhibiting a wide range of variation as regards quantitative characters—from primitive Indian forms to the products of modern selection (see the table).

The range of qualitative characters is not so wide: there are known seeds of 5 different colours and 3 different shapes—from small almost Asiatic forms to broad, flat European ones, etc. The predominance of quantitative over qualitative characters and a greater plasticity of generative characters compared to vegetative ones is in general characteristic of *V. faba*. That is the reason why in drawing up a classification of this species one is guided by the quantitative characters of principally the seeds and fruits. So far as diseases are concerned, the Asiatic forms have proved liable to

Range of Intraspecific Quantitative Variation in Evolution of Beans (*Vicia faba* L.)*

| Characters \ Ecologo-geographic groups | Indian | Pamir-Badakhshanian | Iranian | Daghestan Mts. | Mediterranean | West-European | Central-European | Boreal | Abissinian |
|---|---|---|---|---|---|---|---|---|---|
| Height of plants, cm | 20—45 | 50—85 | 60—90 | 55—85 | 35—70 | 50—85 | 65—125 | 29—65 | 42—50 |
| Size of fruit, cm | 3.4—4.9 | 4.5—6 | 5.7—6 | 5.8—6.2 | 7—13 | 9.2—20 | 6.4—8.9 | 5—8.9 | 5.1—5.5 |
| Size of seed, cm | 0.7—0.9 | 0.7—0.9 | 1.25—1.35 | 0.8—1 | 1.8—3 | 2—2.4 | 0.9—1.55 | 0.8—2.1 | 1—1.1 |
| Weight of 100 seeds, g | 14—20 | 19—42 | 41—56 | 31—48 | 105—256 | 125—255 | 26—60 | 25—125 | 40—45 |
| Veget. period till flowering, days | 26—39 | 28—43 | 43—44 | 34—40 | 21—45 | 21—35 | 31—45 | 21—27 | 24—31 |
| Full vegetative period, days | 96—107 | 95—113 | 128 | 104—108 | 95—133 | 107—140 | 116—142 | 93—106 | 94—102 |

The data refer to the sowings done in the Steppe Experimental Station of the Voronezh province in 1927—1928.

attacks of the rust *Uromyces fabae* Pers., while the European and Mediterranean forms are injured by this fungus rather rarely. The most resistant to drought are, according to A. E. Votchal, the Mediterranean and Central European beans; the northern forms of this country are the most capable to stand out the influence of low temperatures.

After a differential investigation of the characters in their evolution, while account was taken of the quantitative, morphological and biological differences, we have established 17 ecologo-geographic groups: Indian, Kashmirian, Beluchistanian, Pamir-Badakhshanian, Iranian, Daghestan mountainous, Svanetian (*V. narbonensis*), Egyptian, Mediterranean, African mountainous (*V. pliniana*), South-European, West-European, Central-European, Boreal, Japan-Chinese and Abissinian. The most important of them may be characterized briefly as follows.

1. Indian bean—prevailing in the n.-w. India, markedly isolated: low, thin stem; leaves, flowers, fruits and seeds small; poorly productive. Pods not-cracking; period of vegetation rather short.

2. Pamir-Badakhshanian bean—with three subgroups; growing in the regions of Pamir, high-mountainous Uzbekistan, Tadjikistan (Pamir subgroup), Afghan and Soviet Badakhshan (Badakhshanian subgroup), Kabul vilayet (Afghan subgroup). Cultivated lands under this crop reach an elevation of 3100 m above sea level. Watering is always provided, food supply purposes being aimed at. Moderately high stem, middle-sized leaves, short beans, small and very small seeds (Afghan subgroup), difficult to get soft by boiling, of angular shape and as long as broad. Strongly attacked by rust. Mid-ripening and early ripening (Badakhshanian subgroup), resistant to air-drought.

3. Iranian bean—in foothill regions of North Afghanistan, Iran and Uzbekistan; cultivated only on watered land. Moderately high very branching stem (5—7 branches); middle-sized seed, not-cracking pods. Attacked by rust.

4. Daghestan mountainous bean—peculiar form, localized in high mounts of Daghestan (1400 to 2200 m above sea level), moderately high; leaves and beans middle-sized; pods cracking. Seeds small, globular, black and lustrous. Mid-time ripening, productive form. Ground to meal for cookery.

5. Svanetian bean—endemic form too, proper to humid localities of Eastern Georgia, Upper Svanetia. Cultivated 1350—1920 m above sea level, for meal production. Related to small-seed beans of Central-European group, but for its earliness.

6. Mediterranean bean—spreading over whole Mediterranean to Western Iran. Cultivated without watering, usually sown toward autumn. From Mediterranean has been brought to Mexico, Colombia and Bolivia, now also to Japan. Its cultivation in this country is confined to Transcaucasia, being especially successful in Lenkoran district. Stands out by having large leaves, flowers, and seeds of extremely light colour with high ratio of protein. Pods not-cracking. Ripens generally in mid-time, except for some early (Palestinian) and lately (Spanish) ripening strains. Resistant to air-drought, low temperature and rust. Grows quickly when starting development; prolific, stretches down when matured.

7. West-European bean—cultivated in humid mild climate localities of Western Europe. In this country sown rarely as garden crop. Stem strong and thick of middle height with large leaflets. Cracking pods with 2—7 seeds. Seeds large, flat, of different shape and colour, easy to boil soft. Ripens generally in mid-time with high yield of protein; resistant to rust; prolific. Includes best table varieties of European selection: Windsor and Long-pods.

8. Central-European bean—steppe-forest and forest zone of European plain. Ukraine and White Russia are the regions of its cultivation in this country. Characterized by high, strong and thick, not branching stem; large or, rarely, middle-sized leaflets and very large stipule. Pods short and middle-sized, cracking. Seeds small, cylindrical or middle-sized flattened cylindrical, usually of light colour with high ratio of protein. Ripens in mid-time. Rather resistant to air-drought and rust; prolific. Fodder varieties of European and Soviet selection refer to this group.

9. Boreal bean—northern forest zone of both European and Asiatic part of this country, from the Leningrad district to Transbaikal inclusive. Two main subgroups should be distinguished: garden crop with large seeds, not-cracking pods, moderately high stem, and fodder crop with small seeds, low stem, cracking pods attached very low to the stem. Resistant to low temperature, ripening early, especially the small-seed subgroup.

10. Abissinian bean—all over high-mountainous Abissinia where it is used as food article. Occurs also in elevated localities of Eritrea and Arabia. Low stem and small seeds. Ripens early. Protein content in seeds up to 35%.

The ecologo-geographic groups described above are to be regarded as initial material for selection. The varieties available should be improved and through cyclic crosses should give all the possible diversity of types.

By crossing West-European varieties with Mediterranean ones we expect to grow not-cracking and not-stretching large-seed productive forms. Central-European × Abissinian crosses will result in the European group ripening early and yielding not-cracking pods. In order to expand the culture of Central-European form toward the North and make this form early-ripening and cold-resistant, we should cross it with the Boreal or the Svanetian form.

Cyclic crosses between ecologo-geographic groups do thus reveal the phylogenetic interrelation of the latter; they will, moreover, contribute to our knowledge of the evolution of the given species from the primitive small-seed form to the highly cultivated, large-seed forms of modern selection. At the same time the possibility will be afforded to discover the genetic potential of the species for further selection and creation of new valuable forms.

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*DEVELOPMENT MECHANICS*

# THE INFLUENCE OF THYROIDECTOMY ON THE DEVELOPMENT OF DUCKLINGS

By A. A. WOITKEWITSCH

*(Communicated by I. I. Schmalhausen, Member of the Academy, 11. IX. 1938)*

The general growth and development of the plumage in birds subjected to thyroidectomy have been but poorly studied till now. The main reason for that lies, we consider, in the difficulties that arise during the extirpation of the thyroid gland owing to its topography: The methods of thyroidectomy we devised, having profited of the experience of our predecessors, secured both a total extirpation of the thyroid gland and the outliving of the operated birds. It enabled us to scheme and partly effect a series of experiments necessary for the solution of the problem of the connexion between the thyroid gland and form-building in birds, especially with the general growth and development of the plumage. Though numerous investigations have contributed to the elucidation of this question, for its thorough causal solution there is necessary a study of the nature of the morphogenetic processes tak in place in the absence of the thyroid gland.

At present we know only three investigations on the thyroidectomy of birds: G. J. Parhon and C. Parhon(3), Greenwood and Blyth(1), Lektorsky and Kusmina(2).

The data by these autors permit of a general conclusion that the absence of the thyroid gland inhibits the growth of the chickens; the development of the plumage is also retarded, the plumage of the operated birds differs from that of the normal ones. With respect to other birds the question remains unsolved. Parallel experiments on nestling and hatching birds, essentially differing as to the character of their post-embryonic development and dependence of plumage formation on the thyroid gland, as well as experiments performed on species of different intensity of growth and plumage formation within each separate group, would, therefore, be of importance when attempting to make wider generalizations. Studies involving other species are also necessary to find out the nature of the relation existing between the «anlage» and growth of the feathers and the hormone of the thyroid gland. This question is far from being solved by the experiments on chickens mentioned above, since the growth of feathers in chickens begins during their embryonic life. The rôle of this hormone of the thyroid gland in the «anlage» and subsequent growth of feathers can be determined only provided extirpation of the thyroid gland is effected in chickens at a very early age, before the «anlage» of the feather which is practically impossible, or in birds with a late formation of the plumage as, for instance, water birds.

For our experiments we have chosen domestic ducks, birds which have been well studied with regard to their general development and change of plumage. The main experiments were carried out on the Peking duck. Alongside of these we used the Khaki-Campbells. The 15 control ducks were subjected to no treatment except neck incision which was practised to cause a trauma similar to that in operated ducks.

5 ducks from the experimental group were thyroidectomized every five days. In total 35 ducks were operated, out of which 16 had been completely thyroidectomized, as it was shown by further observations of their growth and development of their plumage, as well as by partial autopsies (some of the material was left for further observations). The material concerning the birds in which subsequent autopsies showed a regeneration of the thyroid gland were treated separately. The birds were kept in large cages, receiving equally abundant rations and at the age 45 days were let out on pastures.

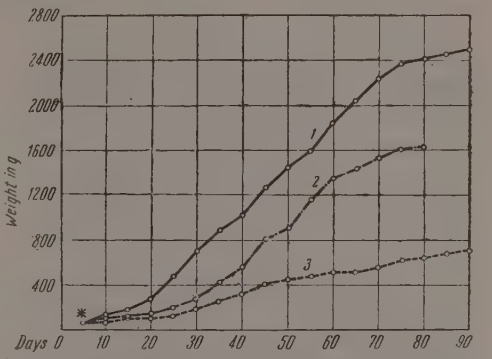

Fig. 1. Growth of control and thyroidectomized ducklings: *1*—control, *2*—incomplete thyroidectomy, *3*—complete thyroidectomy. Date of operation denoted by *.

The curves of Fig. 1 show that the thyroidectomized ducks develop into dwarfs. At the age of three months they weigh on the average 722 g against 2480 g of the control birds. In their behaviour they resemble younger ducklings, greatly differing in this respect from the control birds. They look sufficiently well fed, as one can judge from the presence of fat under the skin and in the cavities of the body.

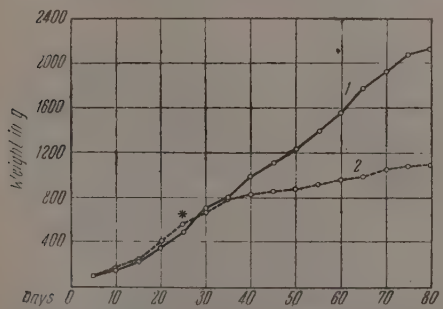

Fig. 2. Growth of control and thyroidectomized ducklings: *1*—control, *2*—complete thyroidectomy. Date of operation denoted by *.

In the cases when partial thyroidectomy is practised, and the thyroid tissue regenerates from a microscopic bit, the growth of the duck proceeds more intensively, but still the birds lag behind in growth, compared to control ones. The inhibition of the growth of such duckling is especially considerable during the first days after the operation, when the thyroid tissue is likely to be but poorly restituted; further on the growth is considerably accelerated.

The weight of the regenerated thyroid glands is approximately a half of that of the control ones. (A similar effect has also been observed in some birds operated at a later age. In a number of cases the regeneration of the thyroid gland could also be observed.)

The inhibition of the growth due to thyroidectomy also takes place in birds operated at a later age. Fig. 2 shows the curves of the growth of the ducks which were operated at the age of 25 days. Immediately after the operation the rate of growth of the ducklings changes but very little. 15 days

after the operation a distinct inhibition in growth is noticed, increasing later on.

Thus, the inhibition in growth, taking place as a result of thyroidectomy, is more pronounced in younger birds. In older ducklings growth is inhibited to a smaller extent. This depends both on the larger size of the bird at the moment of operation and on the «inertia» of growth, probably connected with the presence of the thyroid hormone, preserved in the organism some time after the extirpation of the gland. A similar effect was obtained in the Khaki-Campbell ducks too.

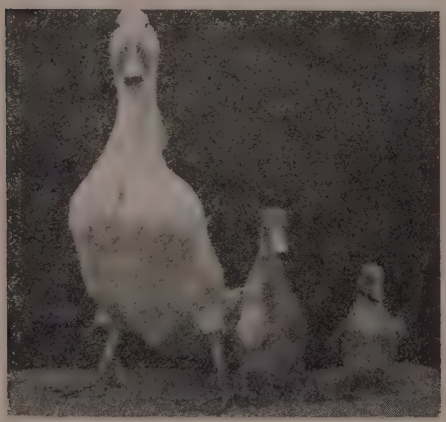

Fig. 3. Development of the plumage, as affected by thyroidectomy; right—5 days old duckling, left—control duckling 52 days old, thyroidectomized when 5 days old.

The development of the plumage in thyroidectomized ducklings greatly differs from that of the control ones. The ducklings operated at the age of 5 days preserve for a long time the yellow down they were covered with at the moment of hatching. Thus, they preserve it on the head even at the age of 80—90 days. Gradually, scarce small feather-tufts appear on the back and especially on the lower side of the body. These tufts are the defective barbs of the upper part of the vane. One may assume that the growth of the feathers stopped at the moment when the point of the barbs appeared on the surface of the skin. The wings remain quite featherless. At the age of 70 days scarce white down begins to appear which gradually covers the whole bird. At the age of 90 days the plumage is usually completely developed in normal ducklings, while the thyroidectomized ducks are totally deprived of contour feathers.

Fig. 4. Khaki-Campbell ducklings 56 days old; right—control duckling, left— duckling, thyroidectomized when 17 days old, middle—duckling subjected to operation at the age of 35 days.

If we compare a 52 days old duckling thyroidectomized when 5 days old with both a control duckling of the same age and a 5 days old one, we become aware that the operated duckling, though somewhat differing in size from the initial state, bears a close resemblance as to plumage development to the 5 days old bird.

The ducklings thyroidectomized at a later age are similar in plumage development to the 5 days old birds. They also remain naked with the only difference that the feather tufts grow somewhat bigger, especially on the

breast. In ducklings thyroidectomized at the age of 25 days, several contour feathers, close to normal in their structure, develop on the shoulder pterilia on the 50th day. On the breast and belly the tufts of the contour feathers are somewhat larger, short, defective rectrices feathers develop too. A similar effect has been obtained in the Khaki-Campbells. We can see on the photo that the control duckling is in the phase of the completion of the plumage growth, while the operated birds remain almost naked, covered only with the remains of the juvenile down and scarce, defective feathers. When incomplete thyroidectomy is practised, the hormone produced by the regenerate proves sufficient for the plumage to develop, though later compared with the control. Especially late develop the primaries.

The introduction of dried thyroid gland (400 mg daily, per os) to thyroidectomized ducklings produced the recovering of the general growth and the development of an almost normal plumage. The development of the plumage in ducklings, which had received thyroidin after the operation, proceeded more intensively than in normal birds (probably owing to an excessive dose). The feathering in these birds is completed earlier, but their final dimensions are a little reduced compared with control birds, which may be put down to the somewhat smaller general size of thyroidectomized ducklings (as compared with normal ones).

Thus, the hormone of the thyroid gland is a necessary factor both for the general growth of the bird and for the development of the normal plumage. Thyroidectomy leads to an inhibition of the ducklings' growth. The degree of inhibition is in inverse relation to the age at which the operation was performed. The development of the plumage of the ducklings proves to be directly proportional to their general development. The thyroidectomized dwarf ducks have a plumage typical for normal ducks of the same size at an earlier age. In connexion with the moment of thyriodectomy the degree of development of the contour feathers can greatly vary, from a total absence to normally developed plumage. When done at the early age, before the growth of the juvenile feathers, thyroidectomy exerts a more pronounced effect on the plumage than at later ages. An operation performed in additional experiments on birds, in which primaries were already growing, does not produce any noticeable effect on the formation of the plumage.

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*DEVELOPMENT MECHANICS*

# GROWTH AND DIFFERENTIATION OF EMBRYONIC MUSCLES IN THE EXTREMITIES OF A CHICKEN

By S. YUDITSKAJA

*(Communicated by I. I. Schmalhausen, Member of the Academy, 17.IX.1938)*

The study of the transformation of the somatic muscles elements and their differentiation without the organism is of high importance, since it facilitates the understanding of regeneration and histogenesis of the striated muscles. The growth of the embryonic muscles in vitro has been observed by many authors; viz., by Harrisson and Goldfretter on embryos of amphibiae, by Lewis, Levi, Olivo and others on chicken embryos. Khlopin goes so far as to assume the growth of juvenile muscles of a rabbit. Most of the authors report the appearance within the zone of the growth of the culture of long polynuclear strings swollen at the ends. In the course of subsequent passages they disappear and the culture gradually becomes homogeneous.

There exists a view according to which a muscle in a tissue culture becomes differentiated and dissolving into mioblasts is transformed into mesenchyma tissue. This opinion is put forward by Levi.

Khlopin occupies a different position; he believes that the differentiated muscular tissues can for a long time be preserved in the culture in the shape of neutral mioblasts, while the muscular tissue of later embryos does not differentiate, but transforms into special symplastic structures. The object of the present investigation was to clear up the question as to the nature of the cells, finally obtained in the cultures grown outside the organism.

For the experiment were chosen chicken embryos after 10—18 days of incubation. The cultures of the extremity muscles were prepared according to the classical method. Usual medium. The culture was cut out every 72 hours, the whole zone of growth being removed as far as it was possible. The longest period of cultivation was 24 days, 7 passages. Fixation was done after Carnoy, Maximov and Susa. The preparations were stained with Karaggi haematoxylin and with iron haematoxylin after Heidenhain. Both total preparations and sections were made of cultures of different age.

Original Observations. The muscular tissue starts to grow directly after explantation. Wide polynuclear muscular bands begin to grow into the zone of growth formed by mesenchymal elements from the central point, where muscular fibres branch in all directions forming peculiar interlacements. They encircle the graft, tending to assume a concentrical distribution. Farther from the centre they grow radially. These muscular bands often possess at the ends mace-like swellings, in which a large number of rounded nuclei is accumulated. Similar formations have already been described by many authors as being typical of the first days of growth of the stria-

ted muscles in vitro. They cover rather a large surface, forming lateral ramifications, being thus able to anastomose with each other and make the whole culture look quite peculiar. Their nuclei are not large, in most cases they are rounded, though we happened to meet oblong ones too. The nuclei are comparatively poor in chromatine and contain one or two well differentiated nucleoli. Sometimes the nuclei catenise along the fibre, but most frequently they are met in groups. The latter are especially characteristic for the mace-like swollen ends of the muscular strings, which are sometimes filled throughout with nuclei. In those sections where the nuclei are situated on the surface, the protoplasm is somewhat raised by the nucleus, forming a tubercle. Later on the amount of protoplasm around the nucleus increases, the nucleus lengthens still more and the whole region separates by fission from the fibre, forming an independent cell, a mioblast.

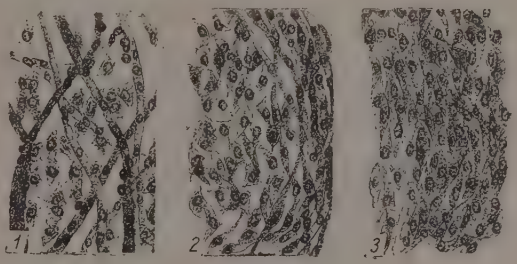

Fig. 1. Changes in the muscular tissue in the centre of the culture. *1*—1st passage, *2*—3rd passage, *3*—7th passage.

The mioblasts may separate by fission both from the fibre proper and from the mace-like swellings. This process is very intensive during the first days of the life in vitro. The separation of mioblasts seems to take place not only within the zone of growth, but also in the centre of the explantate, where all the interspaces among muscular fibres are filled with cells similar to those in the zone of growth. The syncytium mioblasts may differ as to

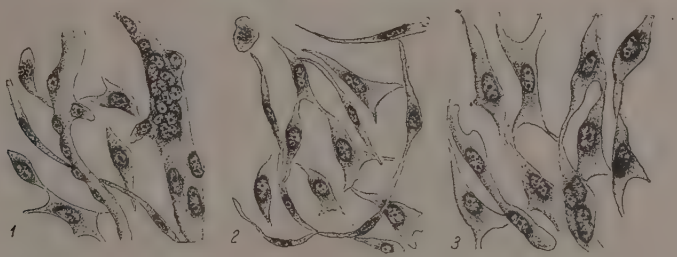

Fig. 2. Changes in the muscular tissue within the zone of growth of the culture. *1*—1st passage, *2*—3rd passage, *3*—7th passage.

their character. Sometimes they are rather small cells with a rounded nucleus and a dark protoplasm, sometimes long, narrow spindle-like elements. Sometimes, at the moment of separation from the fibre, they spread over the glass or mica, flatten out and become like mesenchymal elements. The separating mioblasts propagate most intensively.

Thus, already during the first days of the life in vitro, the striated muscular tissue is represented not only by syncytium polynuclear structures, but by separate cellular elements, viz. mioblasts. Upon subsequent cultivation the latter type of growth which may be characterized as mioblastic begins to prevail, while structures gradually disappear.

Alongside of the wide polynuclear strings with mace-like swellings within the zone of growth, there occur also thin, long fibres, containing narrow, oblong nuclei with pointed ends. Narrow, spindle-like mioblasts can also

separate from them. At first the number of these fibres is not great, but in the second and third passages their number considerably increases, while the wide strings with polynuclear buds disappear. In the second passage we can sometimes find a polynuclear syncytium, but after the third passage they are, as a rule, absent. In the culture there are left only narrow, elongated fibres and mioblasts. These fibres are sometimes very long and can stretch from the centre of the explantate to the very periphery of the zone of growth. They often bend, assuming most various positions, sometimes on the periphery of the zone of growth and even perpendicular to the radius. Things are quite different with respect to free mioblasts. Proliferating intensively, the latter begin to recombine into syncytium, flatten out and become like mesenchymal elements. They possess, however, some peculiarities lacking in fibroblasts.

Quite similar to the wide polynuclear strings, in the subsequent passages the long muscular fibres dissolve into mioblasts. Thus, beginning with the 4th or 5th passage, the culture assumes a homogeneous character, which remains unchanged during the following passages. The whole zone of growth consist of flattened elements, linked with each other by their protoplasmatic offshoots. In the centre of the culture no fibres may be observed any more: we find there solid accumulations of cells which are distributed concentrically. Those cells seem to be of the same nature as the elements within the zone of growth.

We believe the cells at this stage to be mainly mioblasts, simplified under the specific conditions of the life in vitro. They resemble very much to the mesenchymal elements, though they preserve some peculiarities proper to mioblasts alone, namely, one may frequently observe cases of fragmentation of their nuclei. In cultures at the 6th—7th passage one may often observe two- or three-nuclear elements, in cells lying at the edge of the zone one may observe several nuclei that form a compact group and remind of nuclear accumulations of syncytial structures of the first days of cultivation.

Conclusions: 1. The striated muscle of the extremity of a 11—18 days old chicken embryo is capable of growing in vitro.

2. From the very first days the striated muscle grows both as a syncytial polynuclear structure and as separate mioblasts, separating from the muscular fibres.

3. During further cultivation the syncytial structures gradually disappear, giving way to the mioblastic type of growth.

4. Beginning with 4th passage, the culture becomes homogeneous. The main mass of cellular elements consists of simplified mioblasts. In subsequent passages the character of the culture remains unchanged.

5. The simplified mioblasts preserve the capacity of nuclear fragmentation, which is especially conspicuous at the distal end of the zone of growth.

6. The experiments described above enable us to state in agreement with Khlopin that the striated embryonic muscle dissolves into inert mioblasts. In chicken embryos we failed, however, to obsèrve a difference in the behaviour of the muscle in vitro depending on the age of the embryo. We were successful to observe 11 and 18 days old embryos to dissolve into mioblasts.

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*DEVELOPMENT MECHANICS*

# THE INTERRELATION BETWEEN THE FIBRES EXISTING IN THE TISSUE DURING EXPLANTATION AND THE ONES FORMED ANEW IN VITRO

By L. F. BEREZKINA

*(Communicated by I. I. Schmalhausen, Member of the Academy, 17.IX.1938)*

For the last few years, we find a large number of serious investigations in the literature devoted to the problem of histogenesis of fibrous structures. These investigations sufficiently prove the extracellular origin of these structures.

The most convincing evidence has been presented by the authors who studied the fibrillogenesis in vitro.

If Maximov([1],[2],[3]) and his school, as well as Momigliano Levi([4],[5]) and the majority of other investigators payed attention mostly to the very process of histogenesis connected with the problem of the origin of the fibrillae-building material, Rumyantzev and Suntzova([7]) made an attempt to trace in their work the continuity of the material.

Rumyantzev and Suntzova came to the conclusion that it is impossible to explant a tissue, even taken from the youngest embryos, without explanting into the culture, besides this tissue, the basic substance with the elementary fibrillae. Later alongside of the growth of the culture, there begins the organization of the basic substance among the diverging cells, and the fibrillae explanted with the tissue may act as a stimulus for a further growth of the fibres in vitro.

Experiments with explantates consisting of a minimum number of cells made them conclude that the fibres could be formed only in the presence of an intercellular substance organized by the cells. The organization of the basic substance is possible only in the presence of a sufficient amount of cells. Thus, these experiments prove beyond doubt that without fibrillae we are unable to obtain neither a well growing vital culture nor the formation of fibres within the latter.

The question of genetic relations between the old and new fibrillae has for a long time attracted the attention of the investigators.

Levi Montalcini and Sacerdote([6]) undertook a special investigation with the aim to check up the data by Rumyantzev and Suntzova and came to quite opposite conclusions. They consider that the fibrous net explanted with the tissue becomes destroyed—the newly formed net bears no material relation to the former. As conclusive evidence of the validity of their assumption of the independent formation of the new net, they consider the fact that they

succeeded in observing the formation of fibrillae in explantates from a minimum amount of cells in which the fibrous net did either not exist at all, or was in a state of progressive degeneration. It is true that these authors point to the possibility of the existence of thinniest fibrillae serving as a link between the old and the newly formed fibrillae, which failed to be detected solely owing to ineffective staining.

Considering that any observation, however insignificant, may contribute to the elucidation of actually existing regularity, we decided to publish the results of our observations on fibre formation in cultures.

Material and Methods. As material we used strains of fibroblasts, obtained from the hypodermic connective tissue of a 16 days old chicken embryo.

While studying the question of the induction of the formation of the basic substance in the connective tissue, we implanted to the cultures a consistent fibrous connective tissue. The implantation was performed in the following way. The centre of a well growing culture was cut out with a thin knife, some fibrous tissue implanted at the place of the removed one. Already on the next day the implanted tissue formed a whole with the surrounding tissue in the region of growth. After 6 passages, i. e. after 18 days, the cultures were fixed with Zenker-formol and embedded into celloidin-paraffin, and the cultures obtained were stained with azane.

Results. The border of the implanted fibrous tissue was clearly seen on the sections; the fibres were in excellent state of preservation, and stained bright blue.

We saw no signs resembling the degeneration of fibres described by Levi and Sacerdote, nor any degeneration of fibres.

In the preparation where we could see the ends of the fibres, they were not twisted into clumps, as described by Levi and Sacerdote, but either abruptly ended in surrounding tissue or regenerated and grew out abundantly.

At the place of regeneration straight fibres branched off from the ends of the fibres implanted into the culture. Sometimes they were so numerous that a picture of a grass-like growth was obtained. They greatly differed from the fibres of the surrounding tissue twisted in various directions. This proved beyond doubt that they might spring from another source, besides the implanted fibres, and excluded the possibility of confusing them with the thin fibres surrounding the explanted tissue in the zone of growth and growing into the implanted bit.

Moreover, in the tissue surrounding the implanted bit and grown in vitro, we could also notice an intensive formation of fibres. The presence of the implanted fibres seems to induce the formation of the zone of growth in the culture. The most interesting fact for us was that at the place where the implanted fibres joined with the tissue of the zone of growth, viz. at their free ends (the basic bit being totally removed), the fibre formed a single net, consisting of fibres regenerated and newly formed in the explantate. Comparing the results of our investigations with the data by Levi and Sacerdote, we see that the degeneration of the fibrous nettings described by them has not been observed by us. We also observed nothing like the phenomena described by Levi and Sacerdote in the experimental study of the formation of the bone and cartilage(8).

Möllendorff(9) in his work, devoted to the study of the formation of the fibrous and basic substances in the cultures of the connective tissue, does neither mention the degeneration of fibres, though he gives a detailed description of the changes occurring in the maternal bit during prolonged cultivation.

The fibres are not only preserved, but they can grow and only a part of them becomes dissolved.

The experiments by Levi and Sacerdote with the explantation of small bits are not conclusive, since the authors cannot deny that the basic substance gets into the culture. But as soon as it gets there, the fibres and their «anlagen» in the shape of microscopically indistinguishable structure also appear. Levi and Sacerdote do not deny that they have observed fibrous interlacements in the explantates, though in a state of degeneration, neither do they deny the fact that they sometimes were able to observe a continuity between the old and the newly formed interlacements.

Thus, we consider that on the basis of our observations, supporting those by Rumyantzev and Suntzova, we may state that the old fibres serve as a stimulus for the newly formed.

Indeed, if fibres exist in any tissue and the newly formed are connected with them and grow more intensively and abundantly near the already existing interlacements, would it not be reasonable to assume that the already existing is important for the newly formed, inasmuch as this assumption has been confirmed by the experiments of Rumyantzev and Suntzova as well as by ours.

But one of the observations by Rumyantzev and Suntzova we are able to develop. They consider that the well formed collagenal fibres of the friable connective tissue are not capable of further growth. As our observations have shown, the growth or, to be more exact, the vegetation of the fibrous structures is possible, though only in case the majority of the fibres have been preserved.

Thus, on the basis of our experiments we came to the following conclusions:

1. The well formed collagenal fibres being explanted into a well growing culture of the embryonic connective tissue are capable of further growth.

2. Our experiments confirm the deductions by Rumyantzev and Suntzova that the fibres existing in the tissue may serve as basis for the new formed fibres.

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*PALÉONTOLOGIE*

# LA SPONGIOFAUNE FOSSILE DES DÉPÔTS TERTIAIRES DU PAYS CIRCUMBAÏKALIEN

Par H. MARTINSON

*(Présenté par A. A. Borissiak, de l'Académie, le 12.IX.1938)*

Au cours de ces dernières années des études micropaléontologiques des dépôts anciens et, notamment, tertiaires du Circumbaïkalien ont été conduites à la Station Limnologique Baïkalienne de l'Académie des Sciences de l'URSS.

Les matériaux utilisés pour ces recherches consistaient principalement en des échantillons empruntés à des forages et à des affleurements du rivage est et sud-est du Baïkal, faits au cours des travaux de prospection de pétrole.

Vu le caractère continental des dépôts tertiaires, la composition de la microfaune examinée présente un contraste frappant avec celle, propre aux régions pétrolifères ordinaires du type marin. Ainsi, par exemple, les foraminifères, dont l'importance dans la stratigraphie pétrolifère est énorme et qui se rencontrent en masse dans les dépôts des régions pétrolifères de notre Union, font à peu près défaut dans les dépôts tertiaires du Circumbaïkalien. Il en est de même des *Ostracoda* qui, à l'exception de quelques exemplaires (se rapportant au genre d'eau douce des *Candona*), étaient également absents dans ces dépôts.

Par contre, des spicules d'éponges, rencontrées dans diverses couches des dépôts tertiaires, étaient présentes en quantités considérables dans les échantillons examinés. On voit de là l'importance exceptionnelle qui leur revient dans l'étude micropaléontologique des roches sédimentaires du Circumbaïkalien.

Toutefois, l'état peu avancé de nos connaissances portant sur la spongiofaune fossile et la position inerte des spongiaires dans l'évolution phylogénique en rendent encore compliquée et difficile la complète mise à profit dans l'intérêt de la stratigraphie.

Tant à l'époque actuelle qu'aux temps tertiaires les spongiaires sont représentés dans la région du Baïkal par deux familles assez isolées, savoir, celle des *Lubomirskiidae*, éponges baïkaliennes habitant exclusivement le Baïkal et ses golfes, et celle des *Spongillidae*, appelées ici badiagues, cosmopolites, formes d'eau douce typiques.

En fait d'éponges de la famille des *Lubomirskiidae* ont été constatées dans les dépots tertiaires du Circumbaïkalien: *Lubomirskia baicalensis* Pall., *Lubomirskia fusifera* Soukatsch., *Baikalospongia intermedia* Dyb., *Baikalospongia bacillifera* Dyb., *Baikalospongia fossilis* Martinson.

Les spongiaires de la famille des *Spongillidae* sont représentés par: *Spongilla lacustris* L., *Spongilla fragilis* Leidy, *Ephydatia fluviatilis* L.

La diversité des particularités écologiques propres à ces deux familles et la séparation relative de leurs domaines d'habitation qui en résulte permettent de tirer parti de ces formes fossiles non pas tant sous le rapport de la stratigraphie que surtout sous celui de la paléogéographie. Ici, il s'agit de déterminer l'appartenance de l'ancien bassin, siège des dépôts étudiés, soit au Baïkal même et au bassin qui l'a précédé (spicules de *Lubomirskiidae*), soit à des bassins étrangers au Baïkal.

C'est cette signification paléogéographique des spongiaires, intimement liée à l'histoire des origines de la faune du Baïkal étudiée systématiquement par la Station Limnologique de l'Académie des Sciences de l'URSS, qui constitue l'objet essentiel de nos recherches.

Les matériaux examinés, suivant le caractère des conditions ayant donné lieu à la formation des dépôts en question, présentaient des différences quant à la composition de la spongiofaune fossile.

Notre travail a porté sur des échantillons renfermant exclusivement des spicules de *Lubomirskiidae*, sur d'autres ne contenant que des spicules de *Spongillidae* et, enfin, il s'en est rencontré qui comprenaient simultanément des spicules des deux familles susdites d'éponges d'eau douce.

Suivant le caractère de la composition de la faune fossile dans les échantillons, nous avons pu délimiter une série de régions les plus essentielles pour la solution du problème de l'origine et de l'évolution de la faune du lac Baïkal. Parmi ces régions les plus intéressantes pour nous sont la région de la dépression de Tunka et celle des rivières Polovinka et Malinovka.

Il faut bien observer que ces deux régions sont relativement mieux explorées que les autres: les dépôts tertiaires de la dépression de Tunka, par exemple, ont été soumis antérieurement à l'étude au point de vue paléobotanique. On y a étudié tant les restes de plantes supérieures (2), que d'inférieures, d'algues diatomacées (4).

La région des rivières Polovinka et Malinovka, à son tour, a été l'objet des recherches de H. Rammelmeier (3) qui ont permis d'y établir la présence, dans les couches marneuses des dépôts tertiaires, d'une faune de mollusques.

Tant les uns que les autres de ces dépôts ont été, sur la base de la microfaune et de la flore trouvées, rapportés hypothétiquement par I. Palibin et H. Rammelmeier à l'oligocène. Une opinion analogue est soutenue par A. Krishtofovich (1) qui rapporte l'âge des couches correspondantes dans les affleurements avoisinant la rivière Zamaraïkha, dans la dépression de Tunka (en se basant sur des trouvailles de *Trapa borealis* Heer), «à la fin de l'éocène au commencement du miocène», y comprenant ainsi, également, l'oligocène.

La microfaune, dans les échantillons provenant de la dépression de Tunka, est représentée par des spicules tant de *Lubomirskiidae* que de *Spongillidae*. On y a trouvé des spicules de *Lubomirskiidae baicalensis* Pall., de *Baikalospongia intermedia* Dyb. En fait de *Spongillidae*, nous y signalerons la présence de spicules de *Spongilla lacustris* L., de *Spongilla fragilis* Leidy et d'*Ephydatia fluviatilis* L.

La flore aquatique fossile de cette région présente également un caractère particulier en fait de sa composition mixte. D'après les données de A. Žuravleva(4), la flore des diatomacées était composée pour une part de formes ordinaires d'eau douce et pour l'autre, de formes d'eau saumâtre et de mer. Une pareille combinaison spéciale d'éléments de faune et de flore met en relief le caractère du bassin même qui a existé ici, dont les eaux sous le rapport des conditions physico-chimiques jouissaient des propriétés, favorables à l'existence d'organismes d'eau douce typiques et en même temps

de formes, conservant dans une certaine mesure leur qualité de formes propres aux eaux saumâtres et différant essentiellement de celles des petits lacs sibériens fort répandus à cette époque. Quant à la coexistence avec les formes d'eau saumâtre de formes d'eau douce typiques, elle ne saurait être expliquée que par la pénétration passive (avec les eaux) dans le susdit bassin de l'ensemble d'organismes commun à toute la Sibérie, et en particulier des *Spongillidae*, et par la rapidité de leur développement subséquent.

Un ensemble de faune aussi particulier se présente d'une façon plus marquée encore dans la région des rivières Polovinka et Malinovka. En fait d'éponges il n'y existe que des spicules de *Lubomirskiidae*; on y a constaté une forme embryonnaire de foraminifère spirale appartenant apparemment à la fam. *Rotaliidae*, gen. *Discorbis* L. (déterminée par N. Subbotina) et des coquilles de divers mollusques dont certains, voir *Corbula* sp. et d'autres, d'après les données de H. Rammelmeier (3), sont caractéristiques de conditions d'eau saumâtres et marines dessalées.

Ce complexe de faune fossile représente probablement un groupe de formes ayant pénétré dans la région considérée avec des eaux saumâtres-marines dont le dessalement a exercé une action délétère sur ces formes, constatées par nous dans les dépôts tertiaires et depuis éteintes à la seule exception des éponges de la famille des *Lubomirskiidae*. D'autre part, dans une série d'autres régions, comme, par exemple, dans celle de Tankhoï, les dépôts tertiaires sont représentés exclusivement par des sédimentations de rivières, de marécages et de petits lacs caractérisées par la présence de spicules de *Spongillidae* typiques, de préférence de *Spongilla lacustris* L. et de *Spongilla fragilis* Leidy.

Il dérive de ce qui précède qu'aux temps tertiaires (probablement, de la fin de l'éocène au commencement du miocène) deux types de bassins paraissent avoir existé dans le Circumbaïkalien; d'une part de petits lacs, en partie marécageux, peuplés par la faune et flore de l'époque, très répandues dans les eaux douces de Sibérie; d'autre part, un bassin et, peut-être, plusieurs de dimensions beaucoup plus grandes, caractérisés par une population de composition mixte et comprenant tant les formes de faune et de flore largement répandues que nombre de formes du type de celles propres aux eaux saumâtres et marines, ces dernières formes, comme il a été dit plus haut déjà, ne s'étant pas conservées dans le Baïkal actuel, à l'exception des éponges de la famille *Lubomirskiidae*.

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*PALEONTOLOGY*

# SOME RESULTS OF INVESTIGATION OF THE INTERNAL STRUCTURE OF CARBONIFEROUS BRACHIOPODS

By S. N. SEMICHATOVA

*(Communicated by A. A. Borissiak, Member of the Academy, 26.IX.1938)*

Of late the investigation of the internal structure of the shell assumes more and more importance in studying fossil Brachiopods in the Soviet Union as well as in other countries (England, United States, China). The study of the internal structure of the shell, while throwing light upon the structure of those vitally important organs of the animal, often permits of a more precise differentiation of taxonomic units and of a closer approach to knowledge of genetic correlation among Brachiopods, than has been done heretofore on the basis of studying their external form only. Alongside of the great importance that should be attached to the study of the internal structure with a view of elucidating general questions of Brachiopod paleontology, such study is extremely important for the solution of practical questions of stratigraphy. Having worked for a number of years on extensive material on *Spiriferidae* from Carboniferous deposits of this country, I have collected interesting data on vertical distribution of some of the types of internal structure of this group of Brachiopods. Of particular interest are the results derived from studying by means of microsections the internal structure of the apical part of the ventral valve of *Spiriferidae*.

In the Moscow basin in the beds of the Oka series and in the lower part of the Serpuchov beds prevails among *Spiriferidae* the inner structure, characteristic of *Spirifer pseudotrigonalis*, *Spirifer praebisulcatus* described by the author, and of other representatives of the same group. In the beds of $C_1^{s_2p_1}$ this type of internal structure is widespread. Internal structure of identical character was discovered by the author in some *Spiriferidae* from England, as well as from Ferghana, Timan and other localities. Spirifers with such internal structure are referred to the upper part of Lower Carboniferous.

In the lower part of Middle Carboniferous, namely in the Bashkirian stage, occur *Spiriferidae* with a different type of inner structure. This younger type is characteristic of the group *Choristites bisulcatiformis* Semich.: it attains great development in the lower and middle part of the Bashkirian stage in the Urals and in Middle Asia; it is also revealed in Spirifers from the lower part of Middle Carboniferous of the Donetz basin and in material from the lower part $O_2$ from a deep bore-hole No 902 of Sokski district.

In the upper part of Bashkirian beds there appear alongside of Spirifers, closely related, as far as their inner structure is concerned, to those

just above described, such ones whose inner structure bears a different character, considerably approaching the group of *Choristites priscus* Eichw. Higher up, in beds of the Moscovian stage, at every place, where its fauna has been studied from this angle, becomes dominant and widespread among Spirifers the inner structure which is characteristic of the group *Choristites priscus* Eichw. and group *Choristites mosquensis* Fischer (1). In the lowermost portion of the Moscovian stage sometimes still occur forms, distinguished by an internal structure similar to the structure of Bashkirian Spirifers [*Choristites inferous* Ivan. (1)]. Above they disappear entirely.

Thus, if we should meet with wide occurrence of *Spiriferidae* with inner structure similar to that of *Spirifer pseudotrigonalis* m., we may be certain that we are dealing with Lower Carboniferous deposits and most probably with the lower part of the Serpuchov series, as far as the Moscow basin is concerned. The presence of prodigious numbers of Spirifers with the internal structure of the group *Choristites bisulcatiformis* Semich. is characteristic of the Bashkirian stage of Middle Carboniferous; the mingled association of Spirifers having an inner structure of the group *Ch. bisulcatiformis* with the inner structure approaching the group *Ch. priscus* is characteristic of the uppermost Bashkirian beds. The presence of prodigious numbers of Spirifers with an inner structure of the group *Ch. priscus* and *Ch. mosquensis* points to the presence of beds of the Moscovian stage.

Even when we are not in possession of whole shells of Brachiopods and have only fragments not allowing of specific definition, we may within the limit of the upper part of Lower Carboniferous and the entire Middle Carboniferous make an exact deduction not only regarding the division, but also the stage, and sometimes even a definite part of the stage, if it be possible to obtain, in conformity to the present day methodology, prodigious numbers of microsections (or impressions) of the apical part of the ventral valve of Spirifers.

The apical part as the most strongly fortified portion of the shell is usually preserved in a better state than other parts of the shell; the paleontologist often having at hand great number of broken apices cannot make any specific determination whatever; in such cases the above mentioned data will prove very useful for the solution of stratigraphic problems.

They should assume particular significance when treating the material obtained by boring. The experience of analysis of fauna from deep boreholes of the Syzran-Soksky district has shown that into the core of boreholes often penetrate quite considerable numbers of Brachiopods. However, relatively large valves of Spirifers rarely occur in a state of complete preservation, and the identification of the species is in most cases difficult. Rather more frequently one succeeds to obtain an impression or even a microsection of the apical part of the ventral valve.

The utilization of the above data on vertical distribution of separate types of inner structure of Spirifers, enables one on the basis of such material to answer with exactitude the question of geological age of deposits represented by a corresponding section of the stope drill.

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